



Macro-to-micro systems modeling applied to work physiology  
by Robert Raymond Wehrman

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in  
Industrial and Management Engineering  
Montana State University  
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Abstract:

Understanding the human body is critical to modern work design. The following research applies system engineering to human physiology for the purpose of creating a dynamic system model that describes a worker's physiological response to a given task. A secondary goal of this research was to increase the understanding of the human body with respect to work design.

Macro-to-Micro (MtM) systems modeling was chosen as the methodology to describe the system and create the model. The human physiological system is a large scale system. MtM systems modeling provides a modeling methodology that creates successive models at varying levels of detail. MtM systems modeling incorporates the advantages of regression modeling, theoretical modeling, and knowledge about the problem domain to achieve a system model that is composed of one or more detailed sub-models.

A MtM systems model was created based on knowledge about human physiology. The model was validated through expert opinion that the model response appeared to represent the response of the human physiological system. A series of experiments was then conducted for the purposes of "calibrating" the model and conducting validation testing. Five tasks were simulated in the laboratory while physiological measurements were taken. The five tasks included cycle ergometry, arm crank ergometry, load carrying, steady-state lifting, and dynamic lifting (steady-state and dynamic refer to the physiological response over time).

Data from the first two ergometry tasks were used to calibrate the model. Initial model parameters were chosen based on population means and best estimates. The models were repeatedly solved using a gradient search technique to adjust model parameters. The result of the iterative model calibration was a calibrated model for each subject that represented a best fit of the system's responses with respect to oxygen consumption, heart rate and external work.

Data from the remaining three tasks were used to validate the model by comparing MtM model performance to actual measured results and results obtained from regression models by Garg, Chaffin, and Herrin [1]. An analysis of variance was conducted on the steady-state lifting task to test the hypothesis that there were significant differences between the ability of the MtM model or the Regression model's ability to predict the actual steady-state physiological response. The MtM and Garg models were not significantly different at predicting the actual measured steady-state response at the .05 level of significance. Significant interactions between the modeling method (MtM and Garg) with model parameters were detected. It was concluded that the Garg model performed in a similar manner as the experimental data suggested but that MtM model was not as capable as predicting the interaction of the type of lift. This effect can be traced to the fact that the Garg model was a regression model derived from a similar task where the MtM model was a universal systems model that was calibrated for an ergometry task and extrapolated to a lifting task. Other interactions of the analysis were significant but did not yield any physical interpretations.

The carrying task was used to test whether the systems model has the ability to predict a physiological response while being driven with heart rate data as exogenous data. Again the MtM systems model was compared with the Garg prediction equations and the actual measured data. A t-test was conducted in a similar manner as above. It was determined that the Garg prediction equations performed significantly better than the MtM system model at the .05 level of significance.

The final task was a dynamic lifting task and load carrying task with a random workload. The MtM systems model was compared to the Garg prediction equations in a manner similar to the dynamic performance comparison of the previous lifting task. It was found that the MtM systems model was significantly better at predicting the actual measured system's response at the .05 level of significance.

It was concluded that the systems model performed adequately under steady-state and dynamic conditions while being driven from external workload data. It was also determined that the model did not perform adequately while being driven from external heart rate data.

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APPLIED TO WORK PHYSIOLOGY

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of

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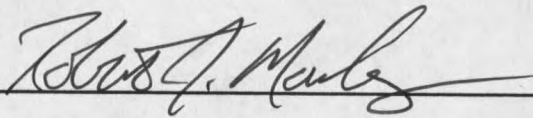
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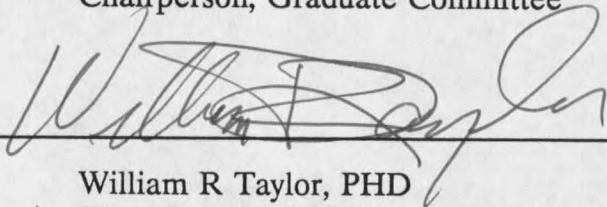
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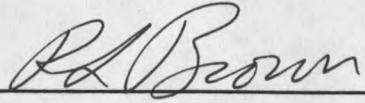
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## ABSTRACT

Understanding the human body is critical to modern work design. The following research applies system engineering to human physiology for the purpose of creating a dynamic system model that describes a worker's physiological response to a given task. A secondary goal of this research was to increase the understanding of the human body with respect to work design.

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Data from the first two ergometry tasks were used to calibrate the model. Initial model parameters were chosen based on population means and best estimates. The models were repeatedly solved using a gradient search technique to adjust model parameters. The result of the iterative model calibration was a calibrated model for each subject that represented a best fit of the system's responses with respect to oxygen consumption, heart rate and external work.

Data from the remaining three tasks were used to validate the model by comparing MtM model performance to actual measured results and results obtained from regression models by Garg, Chaffin, and Herrin [1]. An analysis of variance was conducted on the steady-state lifting task to test the hypothesis that there were significant differences between the ability of the MtM model or the Regression model's ability to predict the actual steady-state physiological response. The MtM and Garg models were not significantly different at predicting the actual measured steady-state response at the .05 level of significance. Significant interactions between the modeling method (MtM and Garg) with model parameters were detected. It was concluded that the Garg model performed in a similar manner as the experimental data suggested but that MtM model was not as capable as predicting the interaction of the type of lift. This effect can be traced to the fact that the Garg model was a regression model derived from a similar task where the MtM model was a universal systems model that was calibrated for an ergometry task and extrapolated to a lifting task. Other interactions of the analysis were significant but did not yield any physical interpretations.

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The final task was a dynamic lifting task and load carrying task with a random workload. The MtM systems model was compared to the Garg prediction equations in a manner similar to the dynamic performance comparison of the previous lifting task. It was found that the MtM systems model was significantly better at predicting the actual measured system's response at the .05 level of significance.

It was concluded that the systems model performed adequately under steady-state and dynamic conditions while being driven from external workload data. It was also determined that the model did not perform adequately while being driven from external heart rate data.

## CHAPTER 1

### INTRODUCTION

In this era of increased competitiveness, managers and engineers should make maximum use of available resources. A major resource of today and in the future is the human resource. Above the financial benefits of effective utilization of human resources is the ethical responsibility to improve the quality of life of the workforce. Improvement involves eliminating hazards, reducing risk of injury, and making tasks more comfortable. The financial benefit of conducting effective human resource management involves such aspects as increased worker productivity, decreased worker absenteeism, lower workers' compensation cost, and higher worker morale.

A key to attaining better human resource management involves developing quantifiable tools to assist managers and engineers in making better decisions which affect the workforce. If particular aspects of the manufacturing system, such as tolerances, production rates, injuries, etc., cannot be measured, they cannot be controlled. One area that eludes accurate measurement is the



human body's ability to undergo various forms of stress without injury and discomfort.

Currently managers and engineers find it very difficult to quantify the physiological demands on the human body. It is possible to measure some physical parameters, such as the oxygen uptake of a worker doing a task. However, the cost of such quantification relegates most models to be used predominantly in research efforts.

The major objective of this research was to develop a more flexible model for quantifying the capacity of the human physiological system. The model could be useful in a variety of applications. The most valuable use involves testing a specific person or population against a computer simulated task to determine if anyone is at risk of injury. The model could provide quantifiable evidence during simulation experiments as to what job parameters provide the best combination to reduce the physiological stress.

A major application of this research involves using the model to quantify the actual workload associated with a specific task during physical simulation while only measuring heart rate. Currently, quantifying the actual workload involves complicated motion analysis and/or experimentation (oxygen uptake). Given a known workload and the physiological capacity of a worker, realistic worker screening is possible.

This research forms the basis for future model expansion. Macro-to-Micro systems modeling was used to develop all models. This type of systems

modeling contains many advantages when synthesizing systems models. The most noteworthy is the ability to expand the modeling effort as more resources become available for model development.

## CHAPTER 2

### LITERATURE REVIEW

#### Work Physiology

##### Worker Performance and Safety

Worker performance and safety are accepted as linked to fatigue. Worker fatigue results in negative effects such as lower productivity, increased errors, lower morale and higher risk of injury.

Astrand and Rodahl [2] state that if an individual works at approximately 30-40% of their aerobic capacity, they will not experience fatigue during an eight-hour workday. To know if an individual is working at a level that will avoid the effects of fatigue, one must know the capacity of the worker and what physiological response the task will elicit. The following is a brief discussion of how worker capacity and task demand are quantified.

### Physiological Work Capacity

Asmussen and Hemmingsen [3] define Physiological Work Capacity (PWC,  $\text{VO}_2$  Max or Aerobic capacity) as the maximum amount of oxygen uptake an individual is capable of. Astrand [4], Bonjer [5], and Robinson [6], show that PWC varies significantly among individuals. A generally accepted physiological workload that can be maintained for an eight-hour workday without experiencing fatigue is approximately  $1/3$  PWC [2]. Knowing the capacity of an individual allows one to know the maximum safe physiological workload to which the individual should be exposed. Several methods exist for determining an individual's PWC.

The most accurate estimate for determining PWC is directly measuring oxygen uptake during a maximal test. A maximal test is a progressively intensive, large muscle, rhythmical task where the subject expends maximum effort while tissue oxygen uptake is measured. Although very accurate, the test is impractical for most industrial settings. Kamon [7] developed a sub-maximal testing protocol used to predict PWC without requiring the exposure to a maximum output. Stegemann [8] proposed a model for calculating PWC knowing a single sub-maximal workload and the individual's heart rate and age.

Experimentation is required for both maximal and sub-maximal determinations of a person's PWC. Wasserman, Hansen, Sue, and Whipp [9] describe population-based regression equations for estimating PWC given an

individual's sex, weight, height, and age. However, these equations do not take into account a person's degree of physical fitness.

### Task Demands

To insure an individual is working below  $1/3$  PWC, the physiological response elicited by the task must be known. This physiological response must match the task demand. There are two distinct methods for determining a task demand. One method is by experimentation. The second method is by using currently available regression equations.

Several researchers have determined the task demand for common industrial jobs. Davis, Faulkner and Miller [10] report results using a generally accepted type of experimentation. Oxygen uptake rates are measured during the conduct of the task. Experimental determination of task demand is very accurate. However, results are only applicable to the specific task, the way the task was conducted, and the individual doing the task, environment, etc..

Garg, Chaffin and Herrin [1] developed regression models for common industrial tasks such that measurable job parameters are input to the models. These regression models allow for the estimation of task demands without experimentation. This adds robustness to models in that they may be applied to a broad range of tasks.

## The Human Physiological System

### Macro View

The human body is a complex system of physical motion and chemical reactions. The body transports chemicals and delivers them in the proper quantities, in the proper location, and at the proper time. The net result of chemical reactions in the human body is the production of energy. The body transforms the energy into motion and heat. Heat transfer modes such as conduction, convection, radiation and/or evaporation, ultimately transport all the heat out of the body. Energy transformed by the body into motion performs external work.

Singleton [11] provides a detailed description of the human physiological system. He states that cells in the body generate the following chemical reaction as work is performed:



Cells in the body use the energy liberated by the reaction to do work. Work completed by the metabolism of food and oxygen in a cell is dictated by the cell type. Muscle fibers contract creating motion, nerve cells produce electrical current, etc.. All components of the basic chemical reaction represent physical

elements. These physical elements have properties that can be measured and/or modeled. An understanding of the physiological system will require examining these elements in more detail.

### Food

Nutrients that enter the body undergo a delay before becoming available to produce energy for useful work. This delay consists of the cumulative time required to complete the chemical reactions and transportation. Nutrients enter the mouth where saliva starts the chemical breakdown. The nutrients continue to the stomach where further chemical breakdown occurs. The cardiovascular system, through the intestinal wall, absorbs the now smaller nutrient chains. The cardiovascular system transports the nutrients to appropriate locations in the body for further chemical change, storage, or use.

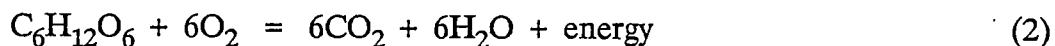
### Oxygen

As with nutrients, oxygen enters the body and experiences delay before becoming available as an oxidizing agent in the process of cellular metabolism (contraction, nervous transmission, etc.). Oxygen enters the mouth and nose and travels to the lungs. The lungs absorb the oxygen into the blood for transportation to the required locations. Oxygen enters the body in the same form that is used for oxidizing nutrients. There is no need for further processing. The only delay experienced occurs during transportation via red blood cells.

## Energy

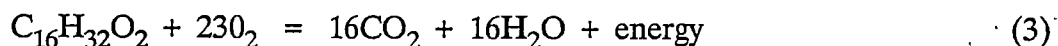
Food, in the basic metabolic reaction, enters the body in any of three forms; fats, carbohydrates, and proteins. These food types are not usable to cells in the body until the energy under chemical bond consolidates into adenosine triphosphate (ATP). Harper and Rodwell [12] cover in detail the metabolism pathways of fat, carbohydrate, and protein molecules into ATP. One mole of each food type will yield a different molar amount of ATP. The result is that each food type has different net energy yields when considering intermediate metabolism.

The net metabolic yield equations for each food type can be written. For example, the net metabolic equation [11] for carbohydrates is:



The reaction releases 686 Kcal of energy per mole of carbohydrate. The caloric equivalent of one liter of oxygen is about 5.1 Kcal (5.05 Kcal by Astrand [2]).

Singleton [11] conducted similar calculations for fats. The net metabolic yield equation can be written as:





for palmitic acid (a 16-carbon fatty acid). The resultant energy yield for the metabolism of fats per liter of oxygen is approximately 4.7 Kcal/L O<sub>2</sub>.

A mixture of fuel types is metabolized. To know the combination of fuels, one may calculate the ratio of oxygen used to carbon dioxide produced. This ratio is known as the Respiratory Quotient (RQ). The non-protein RQ theoretically varies between 1.0 for carbohydrate (6CO<sub>2</sub>/6O<sub>2</sub>) and 0.7 for fat (16CO<sub>2</sub>/23O<sub>2</sub>). Protein contributes little energy for normally fed individuals performing high to moderate work for short time periods. Consequently, for most uses protein metabolism is ignored [2]. One uses the following formula to obtain the energy yield per liter of oxygen.

$$\text{Energy Yield (Kcal/L O}_2\text{)} = 1.333\text{RQ} + 3.766 \quad (4)$$

The energy liberated during the metabolic reaction within a muscle cell is manifested as heat and cellular work, i.e., contraction. Useful work involves motion of the body against a force. For the case of a cycle ergometer, the useful work can be directly measured. Not all work using the muscles involves external work. The heart, for example, consumes nutrients and oxygen and produces work and heat. This work component remains internal and does not contribute directly to the ergometer measurements. Likewise, muscles that maintain body posture do not contribute to the ergometer reading. More discussion on how the

total energy liberated during the metabolic reaction is manifested will be provided later.

### Previous Modeling Efforts

#### Static Regression Modeling

Many researchers have modeled oxygen uptake as a function of energy production. By far, most of these modeling efforts have been static regression models developed from empirical observation. Hagan, Strathman and Gettman [13] conducted a comparative study of 12 regression models for oxygen uptake and energy expenditure during horizontal treadmill running for steady-state conditions. Similar results were obtained for all the models with minor variations in regression coefficients. The models were applicable only for specific ranges of the population and for horizontal running. No further expansion of the models is possible without continued experimentation.

However, other researchers have expanded the applicability of regression models. Garg, Chaffin and Herrin [1] created a series of static regression models for numerous, common, manual material handling jobs. The unique aspect of their approach involved the modeling of effects such as reach distances, repetitions, body postures, etc. Including such factors allows models to be very robust with respect to applying the models to jobs not measured experimentally. Although these models are an improvement over the previous modeling efforts,

some restrictions still apply. The models are not applicable to all industrial tasks. They are still static and only valid for steady-state work conditions.

### Dynamic Regression Modeling

Not all industrial work achieves a steady-state condition. The body's response to a workload increase involves a transient response. This occurs as stored energy supplies are used to meet the short-term demand while oxygen uptake by the body increases to a level required to supply the demand. This transient response of oxygen uptake has been examined by Swanson and Hughson [14], Hagberg, Nagle and Charlson [15] and Morton [16]. All of the model forms are exponential, featuring time and work output as variables. The models are dynamic in nature as they represent the rate of change of oxygen uptake with respect to time. These forms are static in the sense that they are not valid for changing workloads.

The model by Morton [16] takes the form:

$$VO_2 = R_e + Awt + Bw(1-e^{-kt}) \quad (5)$$

Where:  $VO_2$  = Oxygen Consumption

$W$  = Work Rate in kpm

$R_e$  = Resting Metabolic Rate in kpm

$A$  = Regression Coefficient

B = Regression Coefficient

k = Regression Coefficient

t = Time in seconds

Clinical trials were conducted by taking oxygen uptake measurements during a series of running tasks. The model performed reasonably with an  $R^2 = 0.857$ . However, it did have limits on the variables. The major restriction involves workload which must be held constant.

Many industrial tasks involve workloads that change with respect to time. In general, the models were only valid for the initial transient response of oxygen uptake and for limited levels of a constant workload.

A similar transient response occurs when the workload is ceased. This transient response is termed Excess Post-Exercise Oxygen Consumption (EPOC). EPOC occurs primarily to return the body to a normal temperature range and to restore resting chemical, hormonal, and enzyme balances. The extent of EPOC is determined by many factors, such as duration and severity of workload, temperature, humidity, individual differences, and diet.

### Theoretical Modeling

Margaria [17] proposed a hydraulic model to represent oxygen consumption as well as lactic acid formation and phosphagen breakdown. The proposed model was not solved mathematically until Morton [18,19] modified the

model and solved the simultaneous differential equations. The solution to the model did not perform as well as previous regression modeling. It is speculated that the model was incompletely specified.

Morton [16] states that the theoretical modeling of the human physiological system may be mathematically elegant but it is useless in practice. Morton further states that regression modeling is a superior modeling technique, but that significant gains in the science will not occur until such a time that it becomes possible to merge theoretical and regression modeling. This merging will generate models that are robust enough to describe a wider range of tasks and populations.

### Macro-to-Micro Systems Modeling

Historically, "modeling" has followed three distinct paths. The three paths are; theoretical modeling, regression modeling, and systems modeling. Each modeling approach involves unique procedures and tools. This research focuses on the application of systems modeling to human physiology. More specifically Macro-to-Micro (MtM) Systems Modeling as developed by Boyd [20, 21, 22, 23, 24, 25, 26, 27, 28], will be used. For better understanding of MtM systems modeling, the three modeling approaches will be explained briefly with a more detailed description of MtM systems modeling.

### Theoretical Modeling

Theoretical modeling starts with infinitesimal elements of a physical system. The elements are then described by the rate of change of each element. If one element exists, the resulting equation can be integrated to provide useful information. If several elements exist simultaneously and interact with each other, a solution of the simultaneous differential equations is required.

Several limitations of this modeling approach restrict usefulness when applied to systems modeling. The simultaneous equations may be difficult or impossible to solve due to the number of variables. Assumptions need to be made to limit the number of variables. These assumptions are made with respect to the infinitesimal variables; therefore, amplification of error in the solution process may reduce the model to a crude estimate. When simultaneous solutions are obtained after the model is integrated to a higher level, the resulting error, due to missing variables or interactions, may be amplified even further.

### Regression Modeling

Regression modeling is a "shallow knowledge" or heterogeneous approach that centers around available data which represent physical elements of the system. Regression models are developed through the use of statistical tools. As with theoretical modeling, excellent performance can be attained from models of small systems.

A major limitation of regression modeling stems from sparse or missing data and the inability to extrapolate or infer missing data. For complicated systems with many interactions, a great number of physical measurements must be taken. This may be complicated by the inability to measure some critical parameters. Also, it may be difficult to determine the importance of some measurements prior to data collection efforts.

Another limitation of regression modeling is the model's validity. Any model is only valid to the level of detail and range of variation contained in the database. Models may become totally useless for predictions outside the range established by the data. Simply put, at best the regression model is only as good as the data used.

### Systems Modeling

A system is a collection of interrelated components that function in unison to achieve a common goal, end, or objective. Systems modeling is a "deep knowledge" or hierarchical approach. Effective systems modeling combines the advantages of theoretical and regression modeling while minimizing or eliminating the negative aspects. This is accomplished by mixing specific modeling tools of the previous modeling approaches with knowledge about the system.

Macro-to-Micro Modeling. MtM systems modeling is a sequential modeling technique. A level zero ( $L_0$ ) model is created which totally circumscribes the system at its most integrated form. The  $L_0$ , although not usually a mathematically articulated model, serves to establish a system boundary. Progressively differentiated models are developed to articulate the system defined by the  $L_0$  boundary. Each model level is consistent with respect to the amount of detail being articulated mathematically. The modeling effort will continue until a desired level of detail is mathematically articulated to appropriately define the system domain.

The mathematical formulation and iterative solution technique is very analogous to Finite Element Analysis (FEA). In FEA each finite element is exactly similar to a subsystem as described in MtM. FEA is employed typically on a mechanical system that has properties such as geometry, heat distributions, and/or stress distributions that are too complicated to describe and solve with traditional differential equation techniques. A finite element is established that has a linear form with the parameters being modeled such as heat and stress. The system of equations form a balanced set of equations and unknowns when combined with the entire system of finite elements.

The difference between FEA and MtM is the application. FEA is used in conjunction with algorithms that automatically generate the finite elements to fully circumscribe the system. Computational resources are the limiting factor in how many elements are created. In MtM the nature of the system being



modeled does not lend itself to being divided up into subsystems with the use of a generic algorithm. An MtM subsystem is created for a specific purpose. The modeler must explicitly relate each element of the real system to a specific subsystem of the model using knowledge about the system. The distinguishing feature of an FEA model is many generic finite elements as opposed to a few unique and specific subsystems in an MtM model.

All naturally occurring elements can be expressed in terms of their rate and level at any particular time. In addition, time can be considered in discrete increments as a "delta-t" or "time slice." To illustrate, any element can have at the beginning of delta-t, an initial rate (expressed per unit of delta-t) and level. For such delta-t increments, initial rate and level must be equal to the ending rate and level at the end of delta-t. This balance can be expressed as:

$$\begin{aligned} \text{initial level} + (\text{input rate}) \times (\text{delta-t}) = \\ \text{terminal level} + (\text{output rate}) \times (\text{delta-t}) \end{aligned} \quad (6)$$

The balance equation must be consistent from one delta-t to the next, requiring the terminal level of delta-t to be equal to the initial level of the next delta-t.

Rates may depend on a combination of levels and rates.

As with the balance equation, linear regression equations can be written that relate the rate of change of any parameters with respect to other parameters. The net result is a set of linear equations for each delta-t. Given

that systems knowledge is adequate to calibrate the regression parameters, solutions can be obtained for each delta-t time slice in a sequential manner. Starting conditions are established for the first delta-t. From the solution of the first time slice the terminal level is substituted for initial levels of the next delta-t maintaining enough known variables to facilitate a simultaneous solution. This iterative solution technique is exactly analogous to the transient heat transfer models developed with the use of FEA.

The above description relates to a single subsystem. Several subsystems can be connected via balance equations and regression equations. For example, the output of a subsystem can be divided, via a balance equation, into two unique inputs to two respective subsystems. Again, this divided flow is controlled by balance and regression equations of their respective subsystems.

At any one level, all subsystems operate within the same delta-t for simultaneous solution. Likewise, the dimensional units of the elements must be consistent at a given level. For example, if two subsystems are connected, the variables that represent the flow from one to the other must be in consistent units. A linear gain relationship may be used to convert a variable into a consistent unit if required. For example, the conversion of oxygen flow rates in liters per minute to energy flow in Kcal per minute given the energy yield of oxygen is performed using a linear gain, G.

Starting from  $L_0$ , a level-one ( $L_1$ ) model is created by defining subsystems that contain parameters of increased detail. Then, introducing the known

information, solution to the simultaneous equations may be obtained. The resulting model is then subject to verification and validation. Testing is conducted on the model to determine its robustness and if it contains the appropriate system's response. If it is determined that an  $L_1$  model does not display the desired system's response, then the model structure will be revised.

$L_2$  involves dividing the subsystems into even lower level components and interactions. In a similar manner to  $L_1$ , the model is calibrated and tested. Model performance is compared back to  $L_1$  as a "bench mark." This comparison of output with the previous level model is the essence of MtM modeling. It allows complicated systems to be modeled in a consecutive manner by only increasing the detail of the model enough to improve understanding of the system without creating so much detail as to overwhelm the modeler.

### Macro-to-Micro Applied to Physiology

#### Scope and Detail Description

Figure 1 shows the modeling tree used in this research. The shape of the tree represents the increase of detail in the model in the vertical direction for each successive model. Each level of the model, or the model as an entity, is identified by an L with a subscript number. Each subsystem in the model is identified by an L with a series of subscript letters. The letter in the first position is the subsystem in the first level. The letter in the second position is

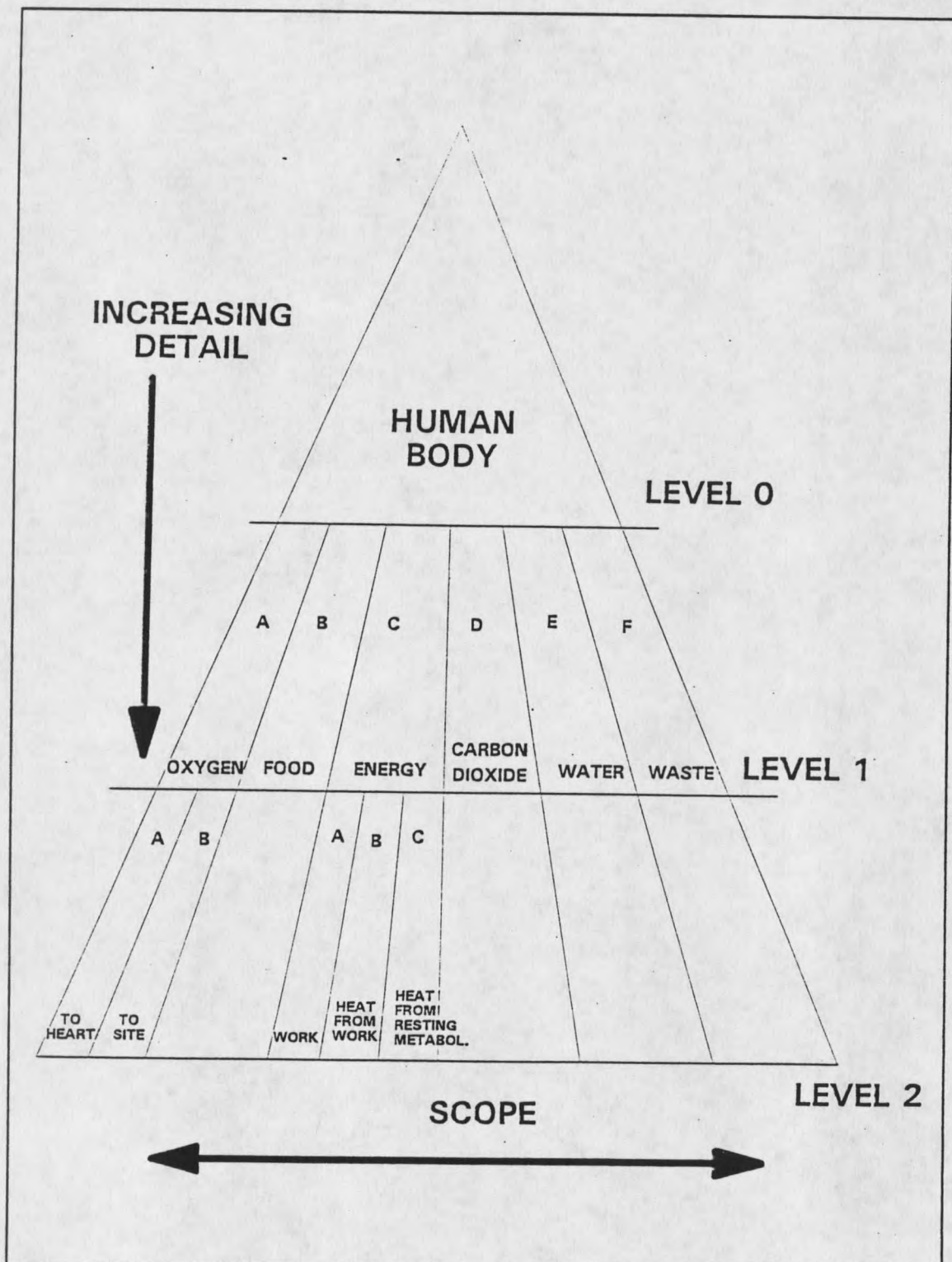
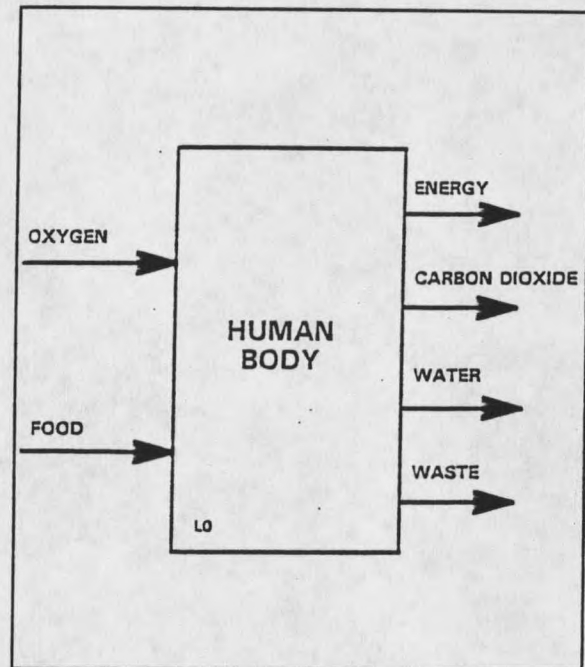


Figure 1. Modeling tree for defining scope and detail of subsystems.

the subsystem of the second level. For example  $L_{c,b}$  identifies the subsystem for heat production found in the  $L_2$  model. Individual element (variable) notation will be defined under model development.

Figure 2 shows a diagram of the  $L_0$  systems model. The  $L_0$  systems model represents the entire human body as a closed system with  $O_2$  and food as inputs, and energy,  $CO_2$ ,  $H_2O$  and solid waste as outputs. The  $L_0$  systems model, a chemical reaction equation, does not contain enough detail to be mathematically useful. However, it does serve to gather knowledge about the system



**Figure 2.** Level zero systems model diagram.

and to establish the appropriate modeling domain.

Figure 3 shows a diagram of the extension from the  $L_0$  to the  $L_1$  systems model, by opening the  $L_0$  "black box." Modeling at the  $L_1$  level allows for the basic metabolic reaction to be modeled in its most integrated form. For the purposes of this research, only the subsystems involving  $O_2$  and energy are mathematically articulated at the  $L_2$  level. The resulting systems model is shown in Figure 4.

At the  $L_2$  level, the model incorporates  $O_2$  transportation mechanism with the heart as an indicator of transportation rate. Also the energy component is

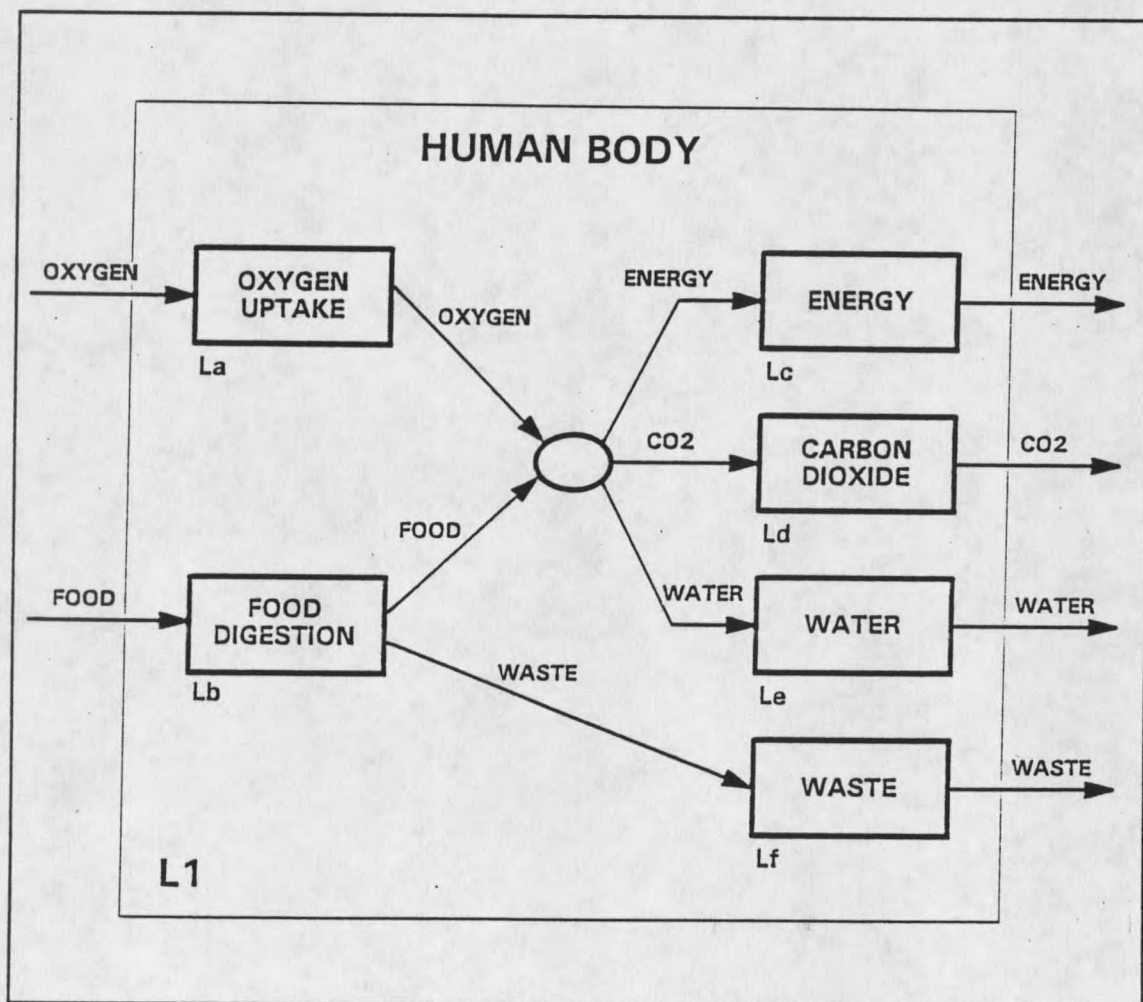
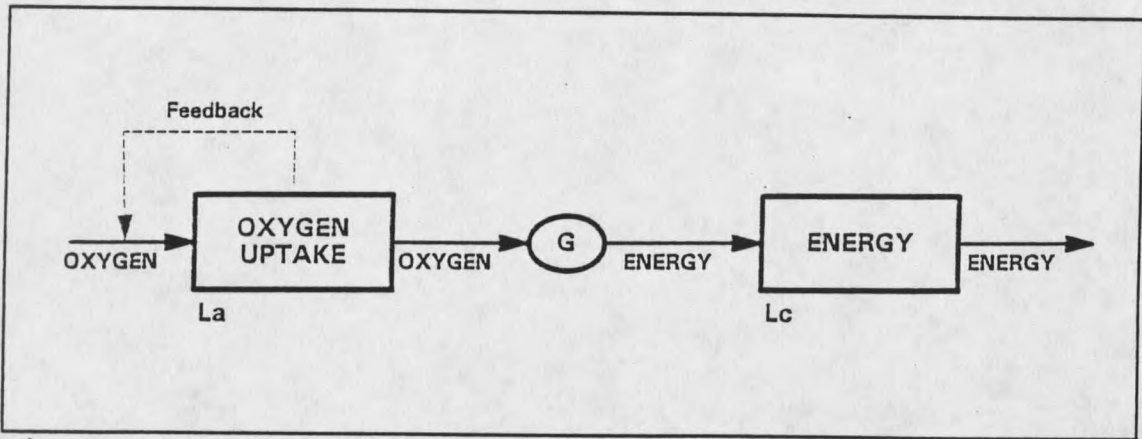


Figure 3. Level-one systems model diagram.





**Figure 4.** Reduced level-one systems model.

modeled in terms of useful work, metabolism, and heat production. Figure 5 contains a systems model diagram of the  $L_2$  model.

### The Proposed Models

The  $L_1$  model is the first level of modeling to be articulated mathematically. Oxygen enters the  $O_2$  subsystem and experiences a delay that represents the transportation to the selected site. The regression equation that triggers the change in  $O_2$  uptake, based on the beginning and ending levels of the  $O_2$  supply in the body, is represented by the dashed line above the subsystem. The gain relationship for converting  $O_2$  into energy is predicated upon the energy yield based on a measured respiratory quotient. Energy for the  $L_1$  model is considered to be instantaneously produced.

The proposed  $L_2$  model is a direct articulation of detail of the  $L_1$  model but with the  $O_2$  transportation subsystem divided into two subsystems. The first subsystem represents  $O_2$  transportation to the heart via blood flow from the

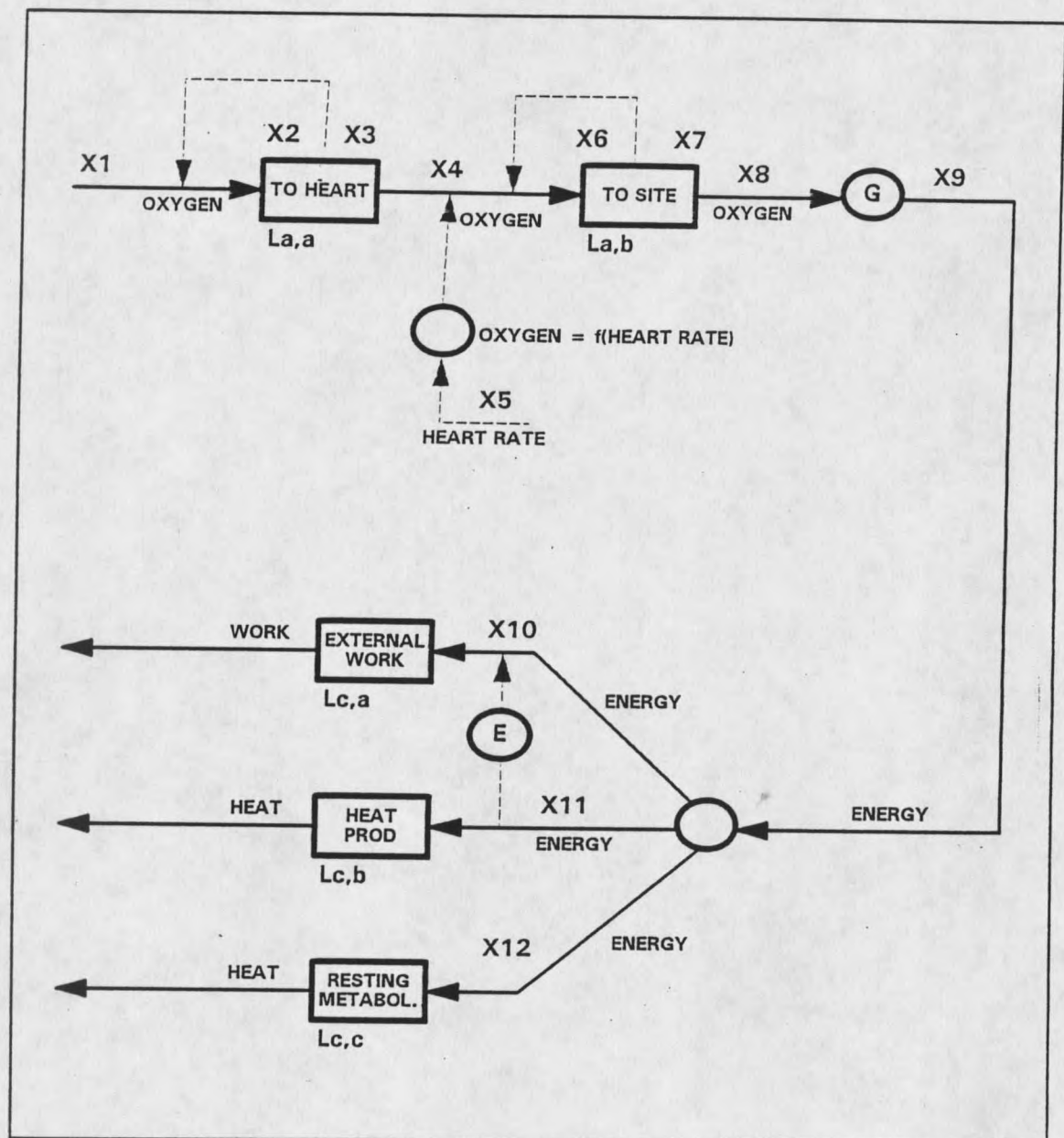


Figure 5. Level-two systems model diagram.

lungs to the heart. The second subsystem represents  $O_2$  transportation from the heart to the desired muscle site via blood flow. Furthermore, energy is divided into three subsystems that represent useful work, heat production due to the workload, and heat production due to the resting metabolism. It should be noted



that total heat production includes heat production due to the workload and heat production due to the resting metabolism. It can be assumed that the resting metabolism is a constant source of heat production that will give the model the required goal seeking characteristics of EPOC (see section on Dynamic Regression Modeling).

The  $L_0$  model lacks the detail to be mathematically useful. The  $L_1$  model has the detail and scope to be mathematically articulated but it lacks the necessary detail to describe, by the appropriate system's response, the goal-seeking characteristics of EPOC. Furthermore, the  $L_1$  model does not allow for the incorporation of heart rate for measuring  $O_2$  uptake rates.

However, the  $L_2$  model addresses the above shortcomings of the  $L_0$  and  $L_1$ . The  $L_2$  model does have several limitations that are not addressed in this research. Some of these limitations involve heat transfer modes, food digestion and Lactic Acid production. Also, the  $L_2$  is not capable of responding to significant changes in aerobic to anaerobic metabolism. More detail will be required to describe this effect. Furthermore, an expansion in scope will be required to incorporate the effects of the intermediate metabolism of food that require energy and  $O_2$ .

Based on the above discussion, it is concluded that mathematically articulating the  $L_2$  model provides adequate system's responses for this research. Mathematical development of the model, verification, and validation does, therefore, involve the  $L_2$  model.

## CHAPTER 3

### RATIONALE AND OBJECTIVES

#### Rationale

Research has shown that a worker's ability to perform a task without risk of injury can be related to the worker's physiological response to the job as well as to the worker's physiological capacity [2]. Much work has been conducted to determine the physiological work capacity of the population and safe work limits related to worker's physiological capacities. The gap in the research that remains to be filled is the ability to predict workers' physiological responses to dynamic job demands.

One method to determine the physiological response of the worker involves measuring oxygen consumption during a given task for each worker. Each result must then be checked against known limits. However, this usually is not practical or even possible in most industrial settings. Therefore, it would be beneficial to develop predictive models for physiological responses.

Many regression models have been constructed that are adequate for the limited bounds of the models' valid space. Some models relate actual external physical job parameters to physiological responses for steady-state conditions. These models cover a large range of tasks and provide parameters that relate directly to the task design. One weakness of these models is that outputs are limited to steady-state conditions and may not be valid when several varying workloads are accumulated. Regression models that operate in the transient period of a workload are limited to that period. Furthermore, the dynamic models do not relate to external parameters of the task. No single model to date accomplishes both simultaneously.

There is a need for a robust model of the human physiological system that adequately models the physiological response with respect to realistic task requirements. A Systems Modeling approach can provide such a model. Systems Modeling incorporates advantages of both theoretical and regression modeling and knowledge about the system. Additionally, MtM Modeling provides a systematic progression of modeling efforts that validate each successive level, which can be expanded and improved.

A systems model can include models such as those by Garg, Chaffin and Herrin [1] as links to the physical external job parameters. The result becomes a robust model that realistically reacts to the changing external workloads.

## Objectives

The following is a list of the objectives for this research:

1. The major objective of this research was to develop a MtM systems model that adequately models the dynamic physiological response to changing workload conditions for tasks involving large, rhythmic muscle movements. The physiological responses will relate to the parameters of oxygen uptake, heart rate, external work, and heat production.
2. To validate the developed model for several common tasks against established models for steady-state conditions as well as validate the model's transient response against precisely measured data.
3. To develop a framework for future model expansion. Expansion will be required if a more accurate response to such parameters as heat transfer mechanisms, dietary inputs, internal chemical regulation, and specific muscle group interaction are desired.
4. To demonstrate how MtM systems modeling can be applied to complex biological systems, such as the human physiological system. MtM systems modeling is a methodology that allows for modeling complex systems that were previously too cumbersome to model with traditional techniques. It

is the desire of this author to expose researchers in other fields to this modeling methodology with the expectation that the systems approach will be beneficial to them.

## CHAPTER 4

### METHODS

#### General Methods

Model development proceeded concurrently with experimentation. An initial, tentative model was formulated to determine if the appropriate system's response was attainable with the proposed model structure. Several experiments were conducted on a cycle ergometer and arm crank ergometer to both calibrate the model and to explore if structure changes might be required. Several issues such as model accuracy, calibration procedure, coefficient sensitivity, and model stability were addressed.

The final stage of the research involved simulating an actual industrial task in the laboratory. Physiological measures were taken in a similar manner as before. Model-predicted-workload, based on heart rate, was compared with measured workload, based on oxygen uptake, as well as workload predicted by Garg, Chaffin and Herrin [1].

## Subjects

The subjects chosen for the experimentation were students of Montana State University. They were five males between the ages of 20 and 30 years, in good health, and of average anthropometric dimensions for their population. Table 1 shows the subject statistics.

All subjects signed the consent form shown in Appendix A. Screening of the subjects involved a questionnaire designed to exclude persons with familial history of heart disease or musculoskeletal problems. This questionnaire is shown in Appendix A. Subjects with resting heart rate greater than 95 or diastolic blood pressure greater than 90 were excluded.

A check was conducted to determine if the five U.S. male students came from the population of U.S. males [34] whose ages ranged between 20 and 30 years and have mean height, weight, and PWC were 175.5 cm, 75.2 kg and 3.431 L/min, respectively. A one-sample t-test was conducted to test null hypotheses that the underlying, population *mean height* and *mean weight* were 175.5 cm and 75.2 kg, respectively. With degrees of freedom taken at 4 and a .05 level of significance, no significant rejections were possible.

A further analysis was conducted to test the null hypothesis that the underlying mean Physical Work Capacity (PWC) was 3.431 L/min. The regression equations defined by Wasserman [9] were used to determine the population PWC and are as follows:

For non-overweight subjects

$$PWC = W*(56.36 - 0.413*A) \quad (7)$$

For overweight subjects,  $W > (0.79*H - 60.7)$

$$PWC = (0.79*H - 60.7)*(56.36 - 0.413*A) \quad (8)$$

Where: PWC = Max.  $VO_2$  in ml/min

W = weight in kg

H = height in cm

A = age in years

With degrees of freedom taken at 4 and a .05 level of significance, no significant rejections were possible.

Thus, based on height, weight, and PWC statistics, it was concluded that the subject population was a random sample taken from the population at large of the same age group. The results of the above test can be seen in Table 1.

### Apparatus

A SensorMedics model 2900c Breath by Breath metabolic measurement cart was used for all oxygen and carbon dioxide measurements. The model 2900c computes desired parameters based on the analysis of the expired breath known as the "open circuit" method. Each expired breath is analyzed after it has



**Table 1.** Subject and population statistics.

| Subject  | age<br>yr | height<br>cm       | weight<br>kg        | PWC <sub>1</sub><br>Exp.<br>L/min |
|----------|-----------|--------------------|---------------------|-----------------------------------|
| 1        | 26        | 180.3              | 91.2                | 4.45                              |
| 2        | 23        | 190.5              | 82.3                | 3.72                              |
| 3        | 28        | 172.7              | 72.1                | 3.95                              |
| 4        | 24        | 177.8              | 109.5               | 4.36                              |
| 5        | 23        | 182.9              | 63.2                | 3.10                              |
| mean     | 24.8      | 180.8              | 83.7                | 3.916                             |
| STD      | 2.16      | 6.575              | 17.875              | 0.545                             |
| Pop Mean |           | 175.5 <sub>3</sub> | 75.200 <sub>3</sub> | 3.462 <sub>2</sub>                |

Small sample comparison concerning one mean for subject height, weight, and PWC with population statistics.

|            |       |       |       |
|------------|-------|-------|-------|
| t          | 1.627 | 0.947 | 1.667 |
| t critical | 2.132 | 2.132 | 2.132 |

Alpha = .05 and degrees of freedom = 4

|   |                                                                                                                     |
|---|---------------------------------------------------------------------------------------------------------------------|
| 1 | PWC determined experimentally using the sub-maximal test.                                                           |
| 2 | PWC determined using the regression model as defined by Wasserman [9] with population mean for weight and 25 years. |
| 3 | Population statistics taken from Pheasant [35]                                                                      |

been conditioned to correct for expired water vapor and ambient environmental conditions. Data are collected by the computer. Several parameters including Oxygen Consumption ( $\text{VO}_2$ ), Carbon Dioxide Production ( $\text{VCO}_2$ ), Respiration Rate (RR), and Volume Expiration (VE) are computed, archived, and sent to the screen and/or printer. For a complete explanation of the equipment, refer to the operations manual [29].

A Polar Vantage XL Heart Rate monitor was used to collect heart rate data. The Vantage XL has a wireless sensor/transmitter that is worn on the chest of the subject. The receiver is contained in a wristwatch style computer. It is capable of sampling and storing the heart rate at desired intervals. The computer is also capable of downloading the data into an IBM PC for automatic data collection and retrieval. Refer to the operator's manual for more details [30].

A Monark Ergometer model 818E was used for all cycle-ergometer experimentation. The model 818E is equipped with a hand brake where the resistance on the brake can be measured in Newtons. Power can be measured in Kilo Joules or Kilocalories (Kcal) for two pedaling speeds of 50 and 60 revolutions/minute. The ergometer is equipped with an electronic meter showing the speed, brake resistance, and power for a target speed. This allowed the workload to be changed easily, with the subject having feedback to maintain proper speed. Refer to the operator's manual for further description [31].

The simulated industrial task, lifting boxes, involved a plastic tote bin and an adjustable platform. The tote bin was a Rubbermaid Roughneck bin with formed couplings on the sides. The formed couplings are located six inches above the base of the bin. Two adjustable surfaces were used. Each surface could be adjusted to the average knuckle and shoulder heights of the subject population. For the squat lift, the subject lifted the tote bin from the floor to the stationary knuckle height surface directly in front of the tote bin. The tote bin

was lowered by an assistant after each lift. The arm lift was conducted by lifting the tote bin from the knuckle height shelf to the shoulder height shelf. The tote bin was lowered in a similar manner as for the squat lift. All lifting was conducted in the sagittal plane.

## Procedures

### Physiological Measures

The resting heart rate (RHR) of each subject was measured after the subject had been sitting upright in a chair for ten minutes. Resting  $\text{VO}_2$  was taken as the steady-state oxygen uptake after a period of sitting upright in a chair for ten minutes. The value for the respiratory quotient was also recorded during this steady-state period.

During all experimentation, oxygen uptake, heart rate, carbon dioxide expulsion, respiratory quotient, respiration rate, tidal volume, and ventilation were measured dynamically for the entire experiment. The data were archived in an electronic format, consistent for automated input into the model. Appendix A contains sample data collection forms.

### Familiarization Period

Each subject was instructed on the use and operation of all equipment prior to any data collection. Each subject was also allowed to have at least one trial iteration on the cycle ergometer task while being connected to all data collection equipment. This familiarization period was intended to allow the subject to make any changes in fit of the equipment and to become familiar with the testing protocol and instrumentation used.

### Determining Physical Work Capacity

Determination of each subject's Physical Work Capacity (PWC) was determined using the sub-maximal technique described by Kamon and Ayoub [7]. The determination of PWC was conducted on the cycle ergometer by measuring heart rate,  $VO_2$ , and workload for three steady-state levels of the workload.

The estimated maximum heart rate (Est. Max HR) was derived from the relationship recommended by Astrand [12] to be:

$$\text{Est. Max HR} = 220 - \text{age} \quad (9)$$

The Heart Rate Range (HRR) is the difference between the Est. Max HR and the Resting Heart Rate (RHR). The levels of the workload were varied to a workload that produces a heart rate that is 35% of the HRR plus the RHR for the first level, 50% for the second level, and 65% for the third level.

Simple linear regression was used to determine a relationship between HR and  $\text{VO}_2$  for the three, steady-state measures. PWC was then determined by extrapolating the regression equation to the Est. Max HR. Table 1 contains the estimated PWC for each of the subjects in the study.

### Experimental Tasks

Five tasks were used to experiment with and/or calibrate the model. These tasks are as follows:

1. Cycle ergometer
2. Arm-crank ergometer
3. Squat/arm lift
4. Load carrying
5. Combination of tasks 3 and 4

The first task involved the Kamon [7] protocol on a cycle ergometer. The duration of each workload was long enough to allow the subject to attain a steady-state oxygen uptake and heart rate. The workload was instantaneously reduced to zero upon reaching the end of the last workload duration. The task was the same used for calculating PWC as well as for providing initial data for calibrating and/or testing the model. The second task involved a repeat of the first task for a hand-crank dynamometer.

The third task was a simulated industrial lifting task. The task involved a sagittal-plane lift, as used by Garg, Chaffin and Herrin [1], to develop metabolic energy expenditures for manual materials handling jobs. The squat lift was from the floor to average knuckle height of the subject population. Four iterations of this task were conducted. The four iterations were combinations of two weights, 5 and 15 Kg. and two frequencies, 4 and 6 lifts/minute. The arm lift was conducted in a similar manner with the lift starting at knuckle height and ending at shoulder height.

The fourth task was the load carrying task. It was conducted on a treadmill. Four iterations of the task were performed using combinations of 1.5 and 2.5 miles/hour and 5 and 15 Kg. loads.

The fifth task was a combination of squat and arm lifting, and load carrying on a treadmill. The speed of the treadmill was set at 1.5 miles/hour. The subject lifted a tote bin from the floor, knuckle height shelf or shoulder height shelf, carried that load on the treadmill for a specified time, then returned the tote bin to the floor or one of the two shelves. A workload profile was created by random sampling. The same work profile was used for each subject. A randomized workload profile was created by; (1), selecting with equal probability the 5 Kg. or 15 Kg. load; (2), selecting with equal probability from which level the load would be lifted; and (3), picking from a uniform distribution from one to five minutes the time to spend carrying the load and then; (4),

selecting from which level the load would be returned. This cycle was repeated after 25 minutes of rest.

### Model Development

The model was developed through experimentation to verify model performance. Three phases of testing were conducted. Phase 1 served to determine each subject's PWC and to conduct initial model experimentation/calibration. Tasks one and two were used for Phase 1. Phase 2 was for the purpose of validating the model against two simulated industrial tasks. Phase 2 testing involved tasks three and four. Phase 3 was used to test the model's performance against a complicated dynamic task, task five.

In Phase 1, each subject was tested with both the first and second task to determine PWC. One trial of both tasks was conducted in random order with a minimum of one day between trials. A model was calibrated for each subject for both tasks. The sum of the absolute error (SAE) was used as a "performance" measure during calibration. SAE is the sum of the absolute differences between the model's output and the direct measure for the variable concerned. In essence, SAE served as a goodness-of-fit for dynamic model response with respect to the measured parameter.

Each data set was calibrated to a separate model. The resulting, model-predicted, time series was compared to the original data for visual purposes. An assessment was made as to the model's ability to articulate a given data set.

For Phase 2, each subject conducted the lifting tasks (squat/arm) in random order in separate, steady-state trials. Model performance was examined. Phase 2 testing formed the basis for validating the model's performance against previously published results for such tasks. For each trial the average steady-state oxygen consumption was calculated based on collected data as well as model-generated data. The predicted energy demand was calculated for each task based on the regression models by Garg, Chaffin and Herrin [1] and converted to an oxygen equivalent.

Phase 3 testing involved the combination task five. In a similar manner model performance was compared with measured data. The average, model-calculated workload, was compared to that calculated from Garg, Chaffin and Herrin [1] in a similar manner as Phase 2 testing.

### Hypotheses Testing

Validation of the model's performance involved Phase 2 experimentation. The null hypothesis was stated that there was no difference between the three mean physiological workloads predicted by three methods. The three methods were the MtM model; the Garg, Chaffin and Herrin [1] model; and, experimentation. A three-way analysis of variance was constructed to accomplish this test. Rejection of the null-hypothesis was considered at the .05 level of significance.



A second null hypothesis was constructed to compare the MtM systems model with the Garg model for predicting dynamic workloads (workloads that change over time) for the same lifting task as above. A performance statistic was defined as the sum of the absolute value of the difference between model output and experimental measurements for each time period expressed as a percent by dividing by the sum of the experimental values for each time period. This statistic was calculated for both the MtM systems model and the Garg prediction equations. The hypothesis stated that there were no significant differences between the performance measures for MtM systems model and that of the Garg prediction equations. A small sample comparison of two means was then performed. Rejection of the null-hypothesis was considered at the .05 level of significance for degrees of freedom of eight.

## CHAPTER 5

### RESULTS

#### Model Formulation

##### Variable Description

Each element represented in the modeling tree represents an element in the physical system. These elements are set one-to-one in correspondence with the model variables. The model is constructed with a combination of linear equations. These linear equations are regression, balance, and equivalence equations.

A "subsystem" forms the basic modeling element. Each subsystem has the ability to transport and/or store oxygen in the system. The storage of oxygen models the transportation delay experienced by a unit of oxygen through the subsystem. For example, the  $L_{a,a}$  subsystem involves four model variables. This subsystem can be seen in Figure 6. The flow of oxygen into the subsystem during time period  $t$  is represented by the rate  $X_1$ . Likewise, the flow of oxygen leaving the subsystem in time period  $t$  is represented by the rate  $X_4$ . The initial

level of oxygen in the subsystem at the beginning of time  $t$  is  $X_2$ . The final level of oxygen in the subsystem at the end of time  $t$  is  $X_3$ .

Each subsystem has at least two equations associated with it. The obvious equation is the balance equation. By inspection one can see the mass balance equation for the  $L_{a,a}$  subsystem is:

$$X_1 + X_2 = X_3 + X_4 \quad (10)$$

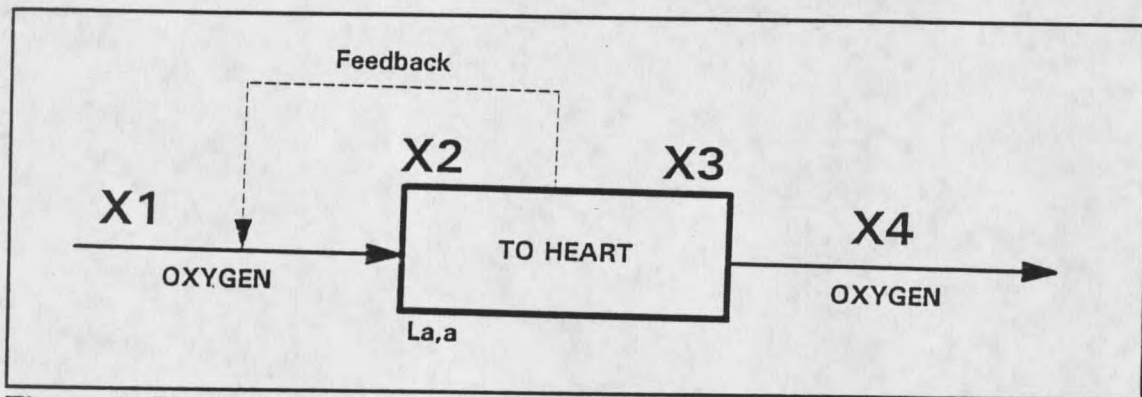


Figure 6. Physical elements set to a one-to-one correspondence with model variables.

Another automatic equation for each subsystem is an equivalence equation. Each subsystem has one initial/terminal pair (IT). An IT pair represents a substitution of the initial value of a level at time  $t$  to be equal to the terminal value of the level at  $t-1$ . The following is an example of an IT pair equivalence equation:

$$X_{2,t} = X_{3,t-1} \quad (11)$$

An initial value for  $X_{2,t}$  must then be supplied or calculated for an iterative solution to be obtained.

The remaining equation can be articulated by a regression equation. A regression equation serves to regress the variable value based on the value of other model variables. For example the rate variable  $X_1$  can be regressed on the two level variables  $X_2$  and  $X_3$  with the following equation:

$$X_1 = C_1 X_2 + C_2 X_3 \quad (12)$$

where  $C_1$  and  $C_2$  are regression coefficients. Knowing enough information about the system for any single time period will allow one to solve for the regression coefficients. This process is referred to as model calibration. One unique property of the above regression equation is that it can be rewritten in dynamic form to give the regression coefficients more physical meaning. The equation can be written as:

$$X_1 = 1/D [\text{Alpha } X_2 + (1-\text{Alpha}) X_3] \quad (13)$$

where  $D$  is the delay factor that represents the time delay for one unit of the variable to travel through the subsystem. Alpha is the shape factor or, the amount of weight either level variable is given. If Alpha equals 0.5, then equal weight is given to each level variable. The system's response of  $X_1$  is noticeably

more sensitive to the value of D. The value of Alpha will only serve to fine tune the system's response if high levels of accuracy are desired and if the system can be calibrated to be theoretically exact. The value of Alpha will be set equal to 0.5, initially, and the value of D will be obtained by calibration.

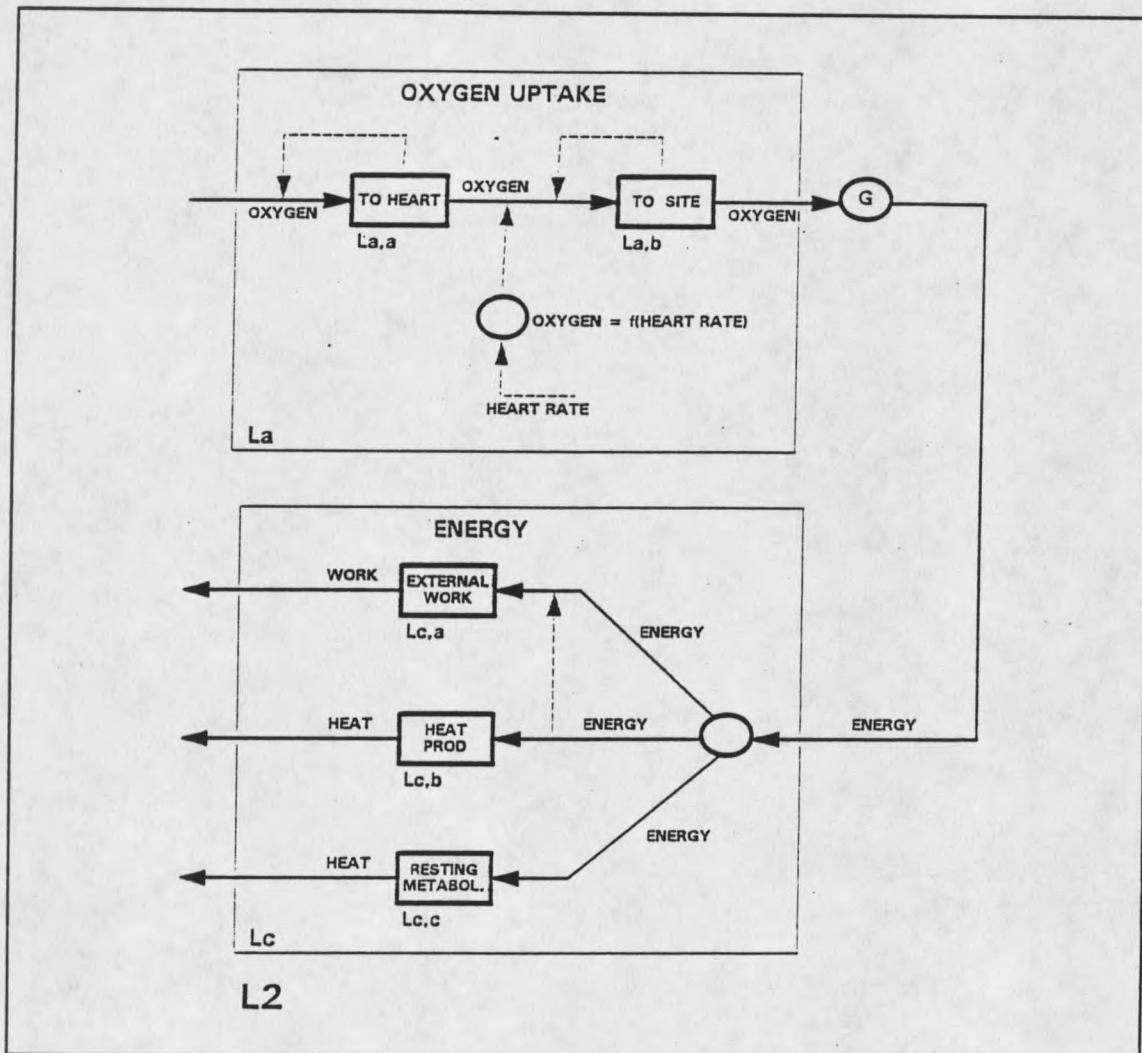


Figure 7. Model variables set one-to-one in correspondence with real world elements within the system.

Employing these basic modeling principles for the three types of equations allows one to formulate the entire model. Figure 7 shows the model variables

for the  $L_2$  model. The dashed lines that connect a subsystem to a rate variable represent a regression equation. Likewise, the dashed line that connects  $X_{11}$  with  $X_{10}$  represents a regression equation that links the amount of heat production due to external work produced via an efficiency relationship. This relationship states that for every unit of external work produced there is a specific number of units of heat produced. The following is the regression equation where  $E$  represents efficiency of heat production to external work done:

$$X_{11} = E X_{10} \quad (14)$$

It is also worth noting that the variables  $X_{10}$ ,  $X_{11}$ , and  $X_{12}$  are the only variables representing their respective subsystems. Because of the assumption that external work and heat production were to be considered as instantaneously produced, the delay imposed by the subsystem is zero. Therefore, the model variables can be reduced to just one for each subsystem. External work follows this assumption physically as it is manifested externally very soon after muscles contract. Heat production does not follow this assumption strictly. Heat produced in the body is transferred out via heat transfer modes that have a significant time delay. For purposes of this research, this time delay will not be modeled. Future research includes the explicit modeling of heat transfer modes.

One will also notice that the oxygen outflow of the  $L_{a,a}$  subsystem is equivalent to the oxygen inflow of  $L_{a,b}$ . This allows the variable  $X_4$  to represent

both quantities. In addition, the variable  $X_5$  represents heart rate. Because  $X_4$  represents the oxygen flow through the heart,  $X_5$  gives an externally measurable indication of the value of  $X_4$ .

With the heart being a pump and heart rate being a measure of the pump flow rate, one can develop a linear relationship of HR to  $VO_2$ . The linear relationship is essentially a statistical regression equation that regresses the oxygen flow rate through the heart based on the heart rate value. The regression equation developed from the data collected during the sub-maximal protocol to estimate PWC will be the same as that used in the model. The following represents the regression equation in model form:

$$X_4 = \text{Coef } X_5 + C \quad (15)$$

The regression equation that links  $X_8$  with  $X_9$  represents the net metabolic reaction. The regression equation takes the form:

$$X_9 = Y X_8 \quad (16)$$

where  $Y$  is the net energy gain per liter of oxygen. The variable  $Y$  was determined from Equation 4 relating energy yield to the RQ.

The summation symbol represents an equivalence equation of the form:

$$X_9 = X_{10} + X_{11} + X_{12} \quad (17)$$

Equation 17 sets total energy metabolized equal to the components of external work, the heat production due to external work, and the heat production due to resting metabolism. It is important to separate heat production due to resting metabolism from heat production due to external work because the former can be constant where the other is not. This effect will give the model the ability to seek a resting state in the absence of external work.

### Vector Table

A vector table associates all model variables with an equation or external data. Model variables that are "unknowns" are related to an independent equation and referred to as an endogenous variable. Exogenous variables are those variables that are defined by external data. The vector table also identifies all IT pairs.

The vector table makes it easy to change the model by redefining variables as endogenous or exogenous, and by changing regression equations. The ability to easily change the model allows the modeler to conduct "what-if" analysis by allowing it to be driven by different variables.

Table 2 captures the model formulation. The initial model formulation allows  $X_{10}$  (useful work) to be modeled as exogenous data. Examining Table 2,



one can see that each model variable is assigned to one of the three types of equations discussed above.

**Table 2.** Vector table to summarize model variables and equations.

| $X_j$    | IT<br>Pair | Model<br>Equation                      | Data<br>Source | Equation<br>Type |
|----------|------------|----------------------------------------|----------------|------------------|
| $X_1$    |            | $X_1 = -1/D_1 [A_1 X_2 + (1-A_1) X_3]$ | Endogenous     | Regression       |
| $X_2$    | I          | $X_{2,t} = X_{3,t-1}$                  | Endogenous     | Equivalence      |
| $X_3$    | T          | $X_1 + X_2 = X_3 + X_4$                | Endogenous     | Balance          |
| $X_4$    |            | $X_4 = -1/D_4 [A_4 X_6 + (1-A_4) X_7]$ | Endogenous     | Regression       |
| $X_5$    |            | $X_4 = \text{Coef } X_5 + C$           | Endogenous     | Regression       |
| $X_6$    | I          | $X_{6,t} = X_{7,t-1}$                  | Endogenous     | Equivalence      |
| $X_7$    | T          | $X_4 + X_6 = X_7 + X_8$                | Endogenous     | Balance          |
| $X_8$    |            | $X_9 = Y X_8$                          | Endogenous     | Equivalence      |
| $X_9$    |            | $X_9 = X_{10} + X_{11} + X_{12}$       | Endogenous     | Equivalence      |
| $X_{10}$ |            | $X_{10} = \text{Exogenous Data}$       | Exogenous      | Data             |
| $X_{11}$ |            | $X_{10} = \text{Eff } X_{11}$          | Endogenous     | Equivalence      |
| $X_{12}$ |            | $X_{12} = \text{RM}$                   | Endogenous     | Equivalence      |

## Phase 1, Ergometry

### Task 1, Cycle Ergometry

Data Preparation. The model required several parameters before the calibration process could proceed. These parameters are the yield (Y), resting metabolism (RM), efficiency (Eff), and linear regression parameters for  $VO_2$  as a function of HR. Appendix C contains the measured data for each subject that was analyzed as well as the subsequent calculations. Column headings that contain "\*\*\*\*" indicate actual measured data. Column headings not so coded have been mathematically converted to the present form. Data were collected breath-by-breath and time averaged every 30 seconds to produce the data in the Appendix B.

The data were analyzed to produce the average energy yield (Y) of one liter of oxygen metabolized. This was obtained by using the regression equation in terms of energy yield as a function of RQ stated earlier as Equation 4. The average energy yield was taken over the entire data set for each subject during calibration.

The value of the resting metabolism (RM), in Kcal/min., was also required. For the beginning and ending of the test, the workload was zero. The last two minutes of each zero workload period were used to calculate RM. The oxygen consumption for each minute was multiplied by that time period's

respective energy yield. An average was then taken of the four time periods.

The value of RM can be seen in Appendix B-F for each subject.

Efficiency was also calculated for each time period. Efficiency as a model parameter is defined as the ratio of useful work, in Kcal/minute, to the amount of heat generated, in Kcal/minute, due directly to the production of the useful work. The last two minutes of each workload phase of the exercise were used to calculate the average efficiency. The value of efficiency can be seen in Appendix B-F for each subject. Efficiency values are not valid for the transient response.

Regression parameters were obtained by simple linear regression between  $X_4$  and  $X_5$  for the three, steady-state, workload phases.  $X_5$  was defined as the dependent variable and  $X_4$  was the independent variable. Appendix B contains the results of the regression. For each subject, the R-squared value was greater than 0.98, indicating good linear fits.

Model Calibration. The parameters stated above were set equal to the appropriate model parameter for each subject. The remaining parameters, D and Alpha for each subsystem, were all set equal to 0.5 arbitrarily. D and Alpha define the shape of the transient response. The time series of the external workload ( $X_{10}$ ) were defined as exogenous data.

The model was then solved for each time period defined for  $X_{10}$ . The model generated time series for oxygen consumption ( $X_1$ ) and HR ( $X_5$ ) was then

compared to the actual collected data for each time period. A performance measure was defined as the sum of the absolute difference between the actual measure and the model's calculated value. Error values for  $X_1$  and  $X_5$  were considerably different due to their different scales. Therefore, a total percent error was defined that normalizes each of the error values and gives them equal weight in the total. The percent error was then defined as the sum of the differences between the model produced value and the actual measure for each time period divided by the sum of the actual measures. Each of the normalized percent errors were then summed to yield a total percent error as the model performance indicator.

Trial and error experimentation yielded a calibration algorithm that minimized the total percent error for each model calibrated. The algorithm involved starting with arbitrary values for the D and Alpha parameters. D for the subsystem  $L_{a,b}$  was changed a small amount and a new solution was obtained. The new percent error was compared to the last. If an improvement was obtained, D was changed in the current direction until a minimum was found. The calibration procedure was essentially a gradient search for the global minimum.

After finding a minimum percent error with respect to D, the Alpha parameter was changed until a new minimum was established. Since the minimum was a function of both the D and Alpha parameters, the cycle had to be repeated at least twice to obtain a global minimum for both D and Alpha in

the  $L_{a,b}$  subsystem. In a similar manner, the D and Alpha parameters for the  $L_{a,a}$  subsystem were changed to produce an even smaller minimum error.

Figures 8 and 9 show typical comparisons of model calculated data with measured data. Exemplar comparisons were shown as the time scales for task 1 were different for each subject. Table 3 shows the parameters used as well as the total minimum percent error for each model calibrated.

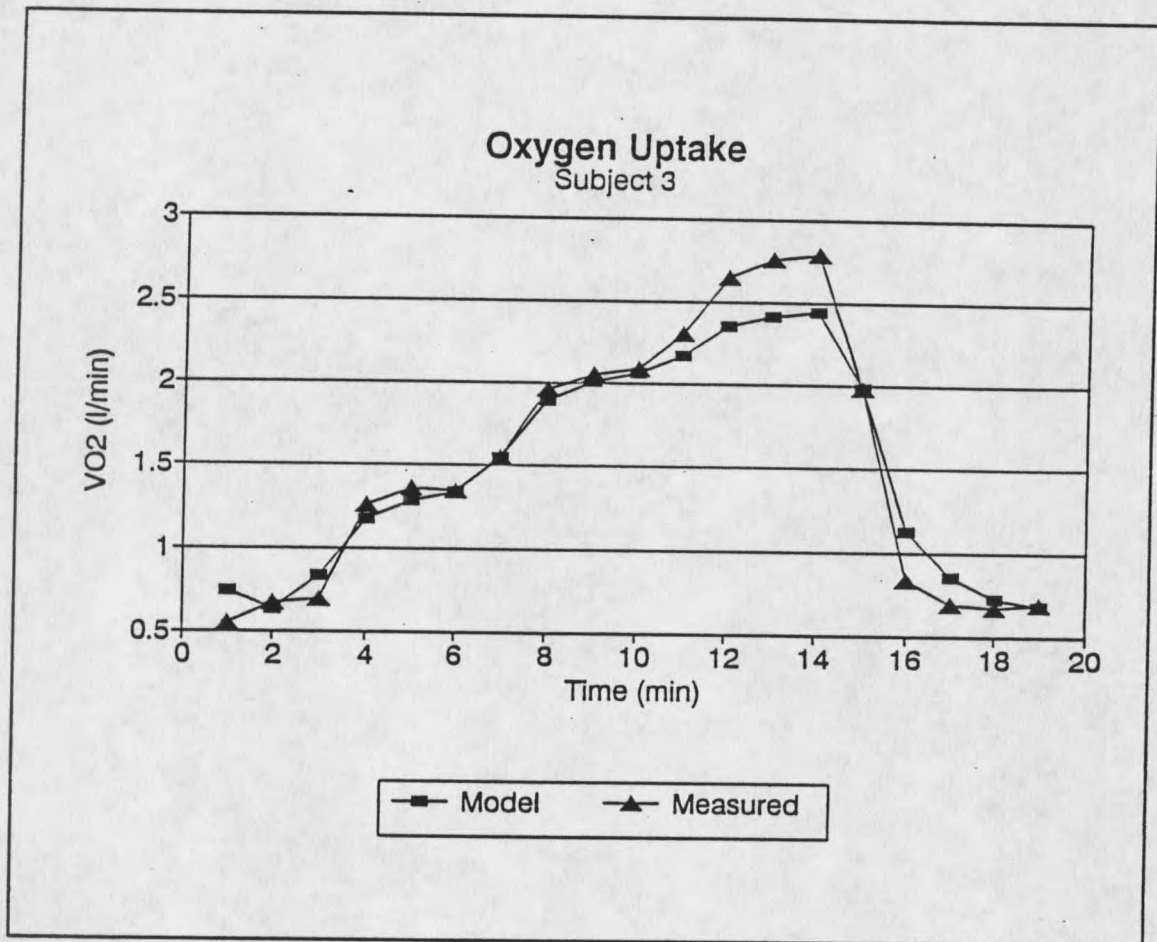
The driving parameter for the model solution was  $X_{10}$ . Therefore, changes in the parameters defining the  $L_{a,b}$  subsystem affected both the VO2 and HR errors whereas changes in the  $L_{a,a}$  subsystem only affected VO2 error. For this reason it was required to minimize the error by adjusting the  $L_{a,b}$  parameters first. Once adjusted, the  $L_{a,a}$  parameters could be adjusted without affecting the previous subsystem error.

Task 1 Observations. Several observations regarding the calibration procedure were considered important. No alternate minima were encountered. This fact was very important as it indicates a smooth solution space that has only one minimum. Attempts were made to start the parameters at values clearly out of range and still the same minimum was achieved. A rigorous proof of the nature of the solution space was not conducted. Faster search algorithms may be possible.

A visual inspection of Figures 8 and 9 show that the model produces the correct system response for three consecutive steady-state workloads. Response

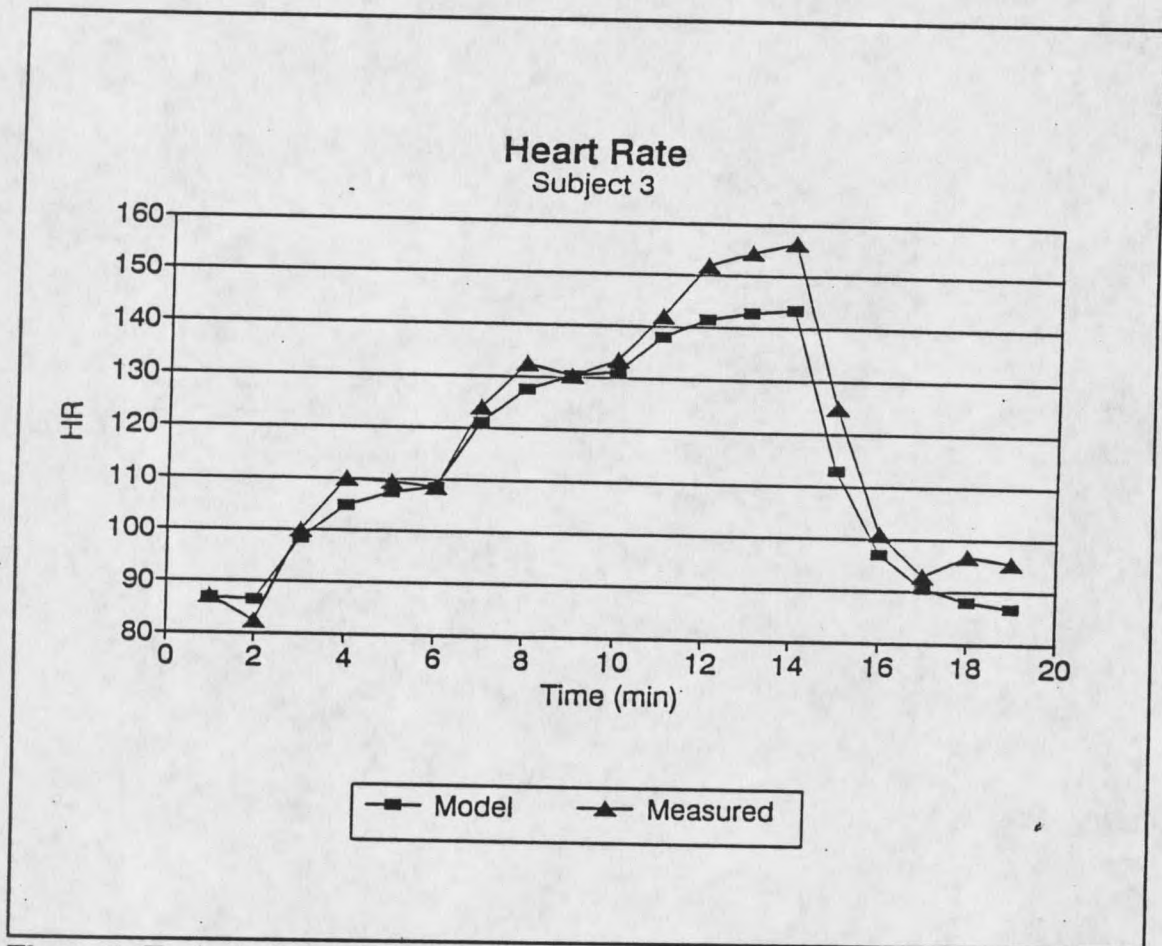
**Table 3.** Summary of model parameters and comparison of model performance with individual population D and alpha parameters for task 1.

| Subject                                                                                          | 1      | 2      | 3      | 4      | 5      | Mean   | STDS  |
|--------------------------------------------------------------------------------------------------|--------|--------|--------|--------|--------|--------|-------|
| Model Parameters                                                                                 |        |        |        |        |        |        |       |
| VO <sub>2</sub> vs. HR reg.                                                                      |        |        |        |        |        |        |       |
| X coef.                                                                                          | 0.035  | 0.029  | 0.030  | 0.034  | 0.029  | 0.032  | 0.003 |
| Const.                                                                                           | -2.320 | -1.965 | -1.963 | -2.258 | -2.477 | -2.082 | 0.205 |
| AVE Yield (Kcal/l O <sub>2</sub> )                                                               |        |        |        |        |        |        |       |
|                                                                                                  | 4.912  | 5.005  | 4.954  | 5.003  | 4.935  | 4.957  | 0.046 |
| Efficiency                                                                                       |        |        |        |        |        |        |       |
|                                                                                                  | 0.320  | 0.310  | 0.308  | 0.259  | 0.331  | 0.313  | 0.007 |
| Resting Metabolism (Kcal/min)                                                                    |        |        |        |        |        |        |       |
|                                                                                                  | 5.138  | 1.136  | 3.176  | 4.695  | 0.697  | 3.150  | 2.001 |
| L <sub>a,a</sub> Sub-system                                                                      |        |        |        |        |        |        |       |
| D                                                                                                | 0.48   | 0.40   | 0.38   | 0.38   | 0.13   | 0.42   | 0.05  |
| alpha                                                                                            | 0.64   | 0.51   | 0.67   | 0.69   | 0.57   | 0.61   | 0.09  |
| L <sub>a,b</sub> Sub-system                                                                      |        |        |        |        |        |        |       |
| D                                                                                                | 0.51   | 1.05   | 0.81   | 0.74   | 1.22   | 0.79   | 0.27  |
| alpha                                                                                            | -0.10  | 0.52   | -0.11  | 0.19   | -0.51  | 0.10   | 0.36  |
| Model Error                                                                                      |        |        |        |        |        |        |       |
| 1. Error with individual calibration                                                             |        |        |        |        |        |        |       |
|                                                                                                  | 7.52%  | 9.36%  | 11.44% | 9.17%  | 17.12% | 9.44%  | 1.96% |
| 2. Error with average parameters (D and alpha only)                                              |        |        |        |        |        |        |       |
|                                                                                                  | 9.34%  | 10.48% | 11.59% | 9.96%  | 17.50% | 10.47% | 1.13% |
| 3. Error with average param. (all but resting metabolism)                                        |        |        |        |        |        |        |       |
|                                                                                                  | 9.11%  | 13.53% | 12.45% | 14.36% | 34.95% | 11.70% | 2.30% |
| Significance test concerning two means with 0.05 level of significance and degrees of freedom 8. |        |        |        |        |        |        |       |
| Test between 1 and 2                                                                             |        |        |        |        |        |        |       |
| t                                                                                                | = 1.02 |        |        |        |        |        |       |
| t crit.                                                                                          | = 1.86 |        |        |        |        |        |       |
| Test between 1 and 3                                                                             |        |        |        |        |        |        |       |
| t                                                                                                | = 1.67 |        |        |        |        |        |       |
| t crit.                                                                                          | = 1.86 |        |        |        |        |        |       |



**Figure 8.** Typical comparison of model calculated oxygen uptake data and actual measured data.

clearly passes through a transient phase and then attains a steady-state value. The most encouraging observation is with respect to the values of  $D$  for both subsystems. One can see from Table 3 that the value of  $D$  for the  $L_{a,a}$  subsystem is less than the value of  $D$  for the  $L_{a,b}$  subsystem and about  $1/2$  its value on average. With  $D$  representing the time delay for a unit of oxygen to travel through the subsystem, this is expected. The distance oxygen travels from inspiration to the heart is considerably less than the net distance oxygen travels



**Figure 9.** Typical comparison of model calculated heart rate data and actual measured data.

from the heart to the site where it is consumed in metabolism.

Reasonable minimum errors were obtained for all but subject five whose error is significantly higher. Appendix B contains the actual data and the components of the error term. One can see that all but about 3.8% of the error can be attributed to the model's ability to fit a curve to the heart rate data. The actual heart rate profile for this subject displays an abnormal response. Even though the response is abnormal, the model predicts oxygen consumption in a



range that is as accurate as the other subjects. The net result of the calibration process is to skew the time delay to cause the  $L_{a,b}$  subsystem to have a larger delay. Because the subsystem error terms have been normalized they have relatively equal weight during calibration. The effect is to force the  $L_{a,a}$  subsystem delay to be small to compensate, thus producing a net delay that is reasonable. This suggests that the calibrated values for D and Alpha for both subsystems are exaggerated by error compensation.

D and Alpha are essentially statistical parameters that define the transient state of the model. It is generally accepted that the transient response for a workload is different than one due to EPOC. In examining Figure 8, one can see that the model response lags during the workload phase and leads during the EPOC phase. Since total percent error was minimized over the entire range of the task, it is expected that the minimum error calibration will yield a model that splits the difference of the non-symmetrical responses. Further accuracy could be obtained by calibrating the model separately for the workload and EPOC phases. Simple logic could be used to change the parameters when appropriate. For the purposes of this research, the accuracy attained with one set of population parameters was considered acceptable for Phase 2 and 3 testing.

A further check involved the model's sensitivity to using population parameters. For the D and Alpha parameters, the mean subject population values, Table 3, were used in each model. The corresponding mean percent error was compared to the mean error with individual calibration. The null

hypothesis was stated that there was no difference between these two means. No significant differences were detected at a .05 level of significance with degrees of freedom of 8. There was an increase of about 1.44% error for each model. Likewise, extremes of the parameters ( $0 < D < 2$  and  $-.2 < \text{Alpha} < 1$ ) were tested with a maximum average error of 15%. Consequently, it is possible that population values for the D and Alpha parameters will yield adequate accuracy for most applications.

Values for Y, Eff, RH and the regression parameters have a major impact on model error. The model is most sensitive to Y and Eff and moderately sensitive to the other parameters. Likewise, the values for these parameters vary significantly for each individual in the subject population. Using population values yielded model errors in excess of 50%. It is suspected that individual values for these parameters must be determined for the model to be of use. It may be possible to use regression equations in the future to predict these parameters given individual variances such as age, height, weight, and physical condition. For the purposes of this research, individual parameters were used for Phase 2 and 3 testing.

The model variables,  $X_2$ ,  $X_3$ ,  $X_6$  and  $X_7$  represent the beginning and ending levels of oxygen for each time period for their respective subsystem. Figure 10 shows a typical model output for these variables. One can see that the value of the variables is always negative. This negative level is not an indication of a negative level from an absolute zero level but rather from an arbitrary

datum set equal to zero. In reality the datum should be set to the resting level of oxygen stored in the respective subsystems. At the time of this publication these datum levels are unknown.

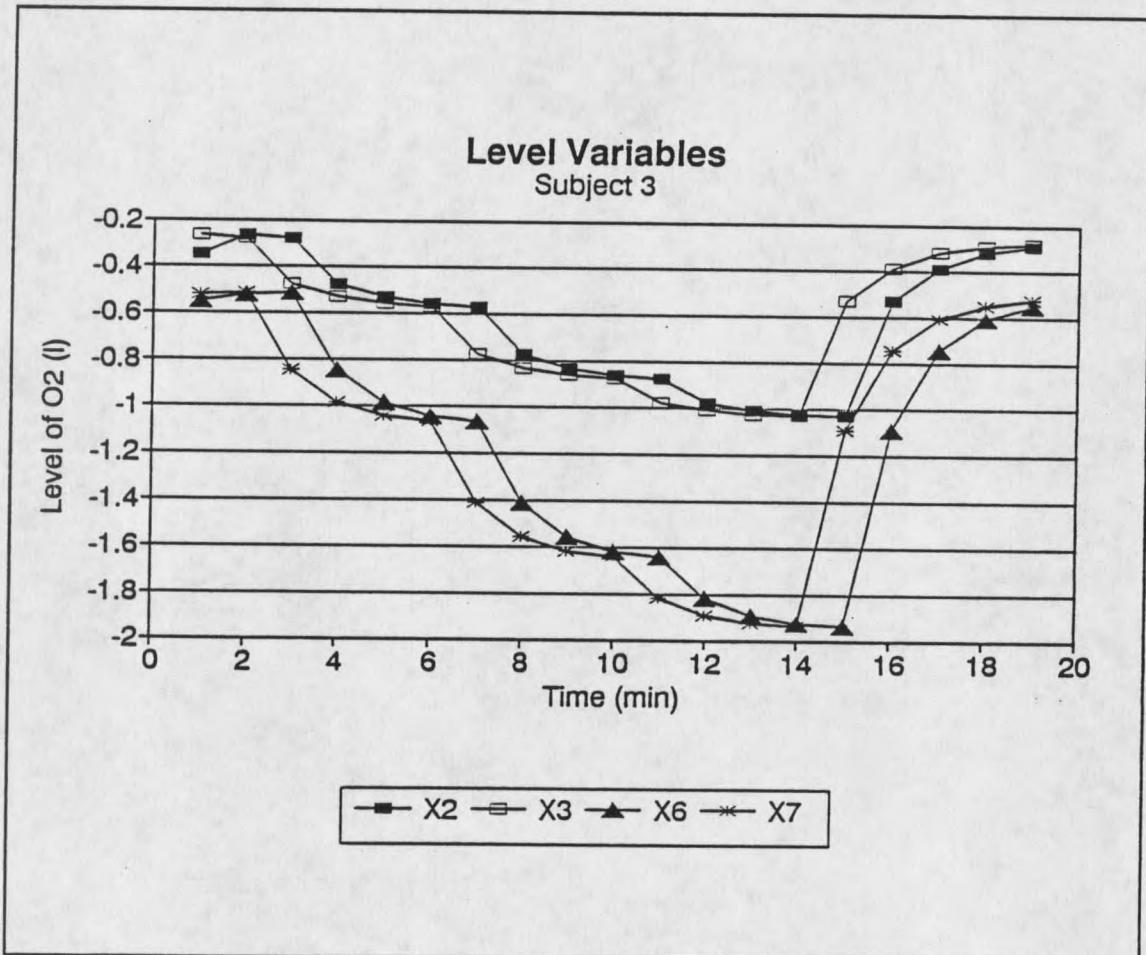


Figure 10. Typical model calculated time series for the level variables in liters of oxygen relative to an arbitrary zero datum level.

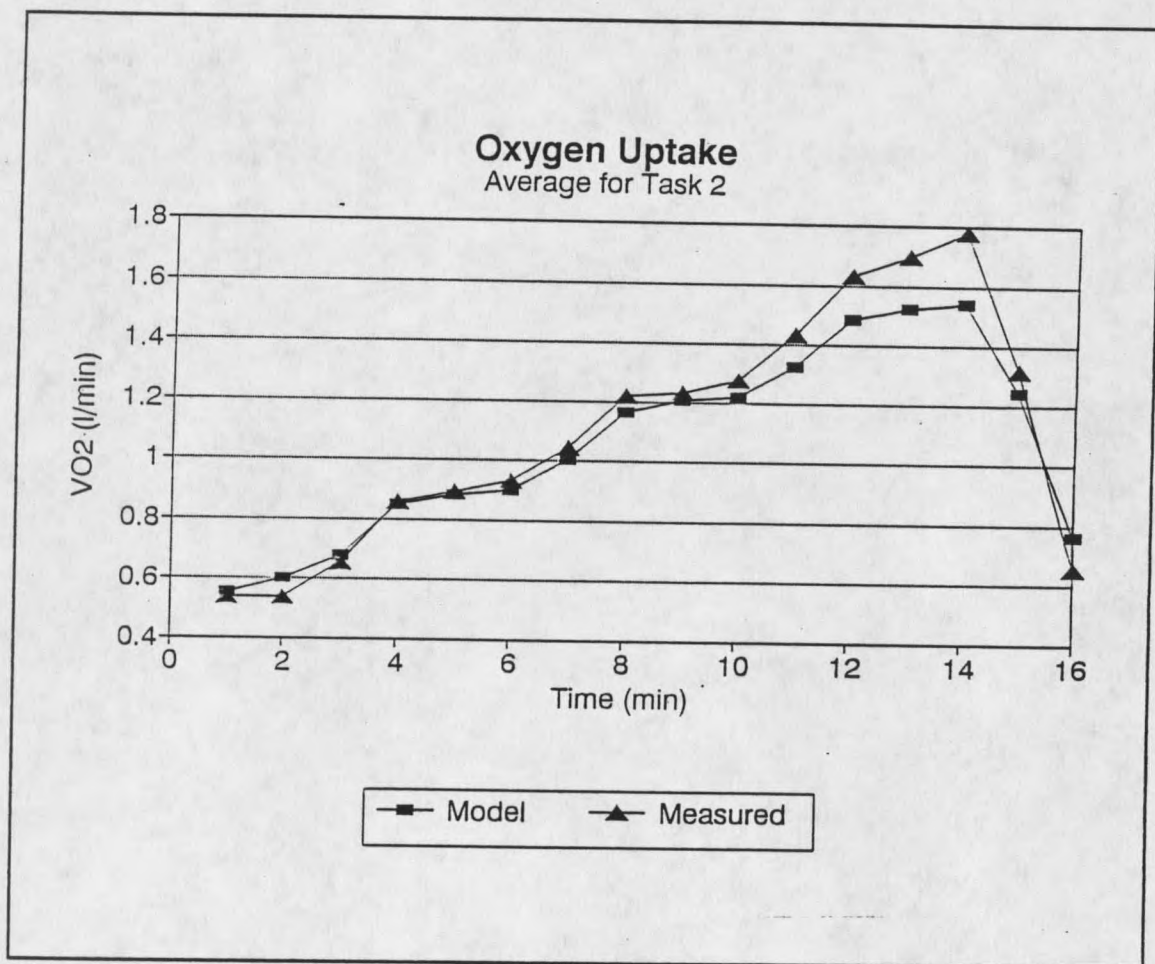
Since the datum levels are set equal to zero, the interpretation of the level variables could represent a change in the level and not the level itself. Given this, one could ask the question, "Why does the  $L_{a,b}$  subsystem have a larger change when the same amount of oxygen is being transported through both

subsystems during steady-state?" The question can be answered by examining the values of the D parameter for each of the subsystems. The value of D for the  $L_{a,b}$  subsystem is about twice the value of D for  $L_{a,a}$  subsystem. It has a physical representation as the time it takes one unit of oxygen to travel through the subsystem. In effect, the level values represent the amount of oxygen being transported through the subsystem during that time period. If the flow time through one subsystem is twice as long as the other, then there is a requirement for twice as much oxygen to be present in that system at steady-state relative to the other subsystem.

## Task 2, Arm Crank Ergometry

Data Preparation. Data were prepared in the same manner as for task one, leg ergometry. Appendix C contains the measured data and subsequent calculations in tabular form.

Model Calibration/Use. The model was calibrated in the same manner as that for task 1. Figures 11 and 12 show average model fits compared with average measured data. Appendix C contains the detailed data. Table 4 shows the results of the calibration process. A similar hypothesis test was conducted to test the mean error associated using population model parameters instead of individual parameters.



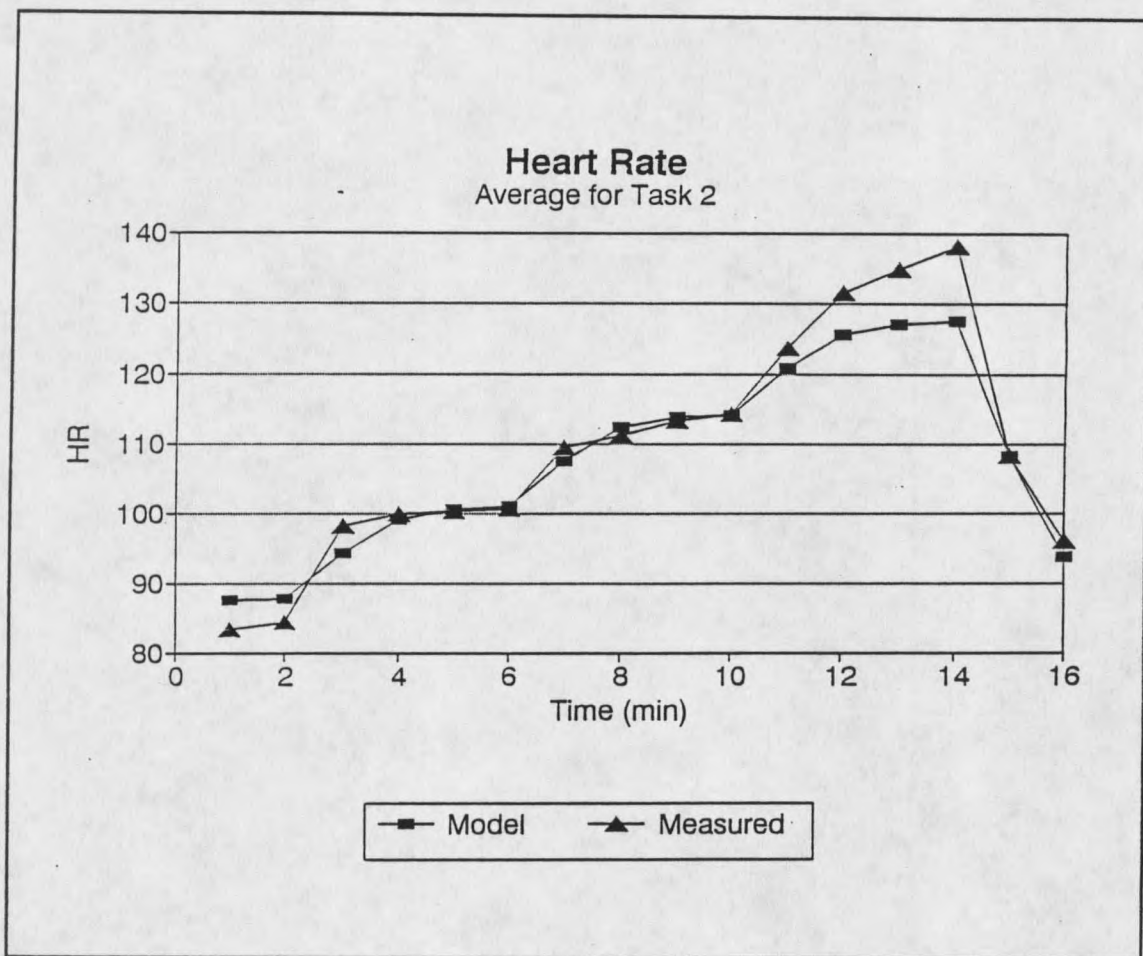
**Figure 11.** Comparison of average model calculated oxygen consumption with average measured oxygen consumption for task 2.

**Task 2 Observations.** The model calibrated with task 2 data displayed similar characteristics as for task 1 data. One can see from comparing the D and Alpha parameters of both tasks 1 and 2 that they are similar with the exception of the negative values of Alpha for task 1. It is unknown what the occurrence of negative values indicates. It is possible that experimental error associated with task 1 data for the subjects caused negative Alpha values.

**Table 4.** Summary of model parameters and comparison of model performance with individual and population D and alpha values for task 2.

| Subject                                                                               | 1      | 2      | 3      | 4      | 5      | AVE    | STDS  |
|---------------------------------------------------------------------------------------|--------|--------|--------|--------|--------|--------|-------|
| Mode Parameters                                                                       |        |        |        |        |        |        |       |
| VO <sub>2</sub> vs HR reg.                                                            |        |        |        |        |        |        |       |
| X coef.                                                                               | 0.027  | 0.014  | 0.026  | 0.024  | 0.026  | 0.022  | 0.007 |
| Const.                                                                                | -1.357 | -0.441 | -1.686 | -1.587 | -2.149 | -1.161 | 0.645 |
| AVE Yield (Kcal/l O <sub>2</sub> )                                                    |        |        |        |        |        |        |       |
|                                                                                       | 5.009  | 5.048  | 4.994  | 5.028  | 5.076  | 5.017  | 0.028 |
| Efficiency                                                                            |        |        |        |        |        |        |       |
|                                                                                       | 0.234  | 0.368  | 0.259  | 0.211  | 0.241  | 0.287  | 0.072 |
| Resting Metabolism (Kcal/min)                                                         |        |        |        |        |        |        |       |
|                                                                                       | 3.507  | 3.556  | 2.201  | 3.379  | 2.004  | 3.088  | 0.769 |
| L <sub>a,a</sub> Sub-system                                                           |        |        |        |        |        |        |       |
| D                                                                                     | 0.24   | 0.20   | 0.24   | 0.15   | 0.13   | 0.23   | 0.02  |
| alpha                                                                                 | 0.68   | 0.50   | 0.55   | 0.55   | 0.52   | 0.58   | 0.09  |
| L <sub>a,b</sub> Sub-system                                                           |        |        |        |        |        |        |       |
| D                                                                                     | 0.38   | 1.12   | 0.66   | 0.86   | 0.36   | 0.72   | 0.37  |
| alpha                                                                                 | 0.37   | 0.54   | 0.04   | 0.43   | 0.50   | 0.32   | 0.25  |
| Model Error                                                                           |        |        |        |        |        |        |       |
| 1. Error with individual calibration                                                  |        |        |        |        |        |        |       |
|                                                                                       | 6.77%  | 12.49% | 8.94%  | 6.08%  | 10.19% | 9.40%  | 2.89% |
| 2. Error with average parameters (D and alpha only)                                   |        |        |        |        |        |        |       |
|                                                                                       | 9.51%  | 13.25% | 9.26%  | 6.15%  | 11.04% | 10.67% | 2.23% |
| 3. Error with average param. (all but resting metabolism)                             |        |        |        |        |        |        |       |
|                                                                                       | 16.24% | 19.02% | 15.10% | 25.78% | 34.38% | 16.79% | 2.02% |
| Significance testing (based on 0.05 level of significance and degrees of freedom = 8) |        |        |        |        |        |        |       |
| Test between 1 and 2                                                                  |        |        |        |        |        |        |       |
| t                                                                                     | = 0.78 |        |        |        |        |        |       |
| t crit.                                                                               | = 1.86 |        |        |        |        |        |       |
| Test between 1 and 3                                                                  |        |        |        |        |        |        |       |
| t                                                                                     | = 4.69 |        |        |        |        |        |       |
| t crit.                                                                               | = 1.86 |        |        |        |        |        |       |





**Figure 12.** Comparison of average model calculated heart rate with average actual measured heart rate for task 2.

### Phase 1. Conclusions

From Table 5, one can add the two average values for the D parameter to get the net flow time of oxygen in the body. For the leg ergometry task, the flow time is approximately 1.2 minutes and for the arm crank ergometry 0.95 minutes. The flow time for oxygen in the human body is the net time that a unit of oxygen takes to enter the body and travel to the site where it is utilized in metabolism. This delay will serve as a benchmark for future model expansion. If the model is

expanded to include the division of the flow to various sites in the body, the sum of the delay times must add up to the delay obtained from this level of modeling.

## Phase 2, Lifting & Carrying

### Task 3, Squat/Arm Lifting

Data Preparation. Data were prepared in the same manner as for the previous tasks. The only exception was in determining the external work. In tasks 1 and 2, the value was obtained from the ergometer. However, for task 3, the change in potential energy of the load was calculated for each lift. The value was then scaled by the lifting rate per minute to obtain the external work in terms of Kcal/minute for each type of lift.

The data were collected in three trials with three observations, and two types of lifts respectively in each trial. The time series for all three trials were combined into one time series for oxygen consumption, heart rate, and external work. Appendix D contains the data collected as well as the subsequent calculations to prepare the data for the model.

Model Use. The external workload time series ( $X_{10}$ ) was established as the exogenous data set similar to tasks 1 and 2. The model was not calibrated. Instead, the calibration coefficients obtained from tasks 1 and 2 were used as well as the average of the calibration coefficients (pooled calibration coefficients)



from both of the previous tasks. Thus, the model solution was obtained for three sets of calibration coefficients. The values for the efficiency, yield, and resting metabolism were taken from the experimental data similar to tasks 1 and 2.

A solution, for the endogenous variables, was obtained by using each of the three sets of calibration coefficients. Appendix D contains the results of the model.

The sum of the absolute differences was calculated and used as a performance measure for calibration. A paired t-test was conducted to determine if there was any significant difference in the MtM model's performance relative to the calibration coefficients. The sum of the absolute difference is calculated as the sum of the absolute difference between the measured data point and the model predicted data point. It was determined that at the 0.05 level of significance there was no significant difference. Based on this analysis it was determined that using the pooled calibration coefficients would not significantly add to the error of the model.

Model Validation. The model solution was obtained by using the pooled calibration coefficients from tasks 1 and 2. The model was validated by comparison of the model's performance in both steady-state and dynamic analyses with both the actual measures and the Garg prediction equations.

The steady-state energy expenditures were calculated from the Garg prediction equations, the actual measured values, and the system model, resulting

**Table 5.** Data set used for the analysis of variance to compare the model's steady-state performance against the actual measures and the Garg prediction equations.

| Subject                    |         |                 | 1     | 2     | 3     | 4     | 5     |
|----------------------------|---------|-----------------|-------|-------|-------|-------|-------|
| Lift Type                  | Load kg | Freq. Lifts/min |       |       |       |       |       |
| Garg Prediction (Kcal/min) |         |                 |       |       |       |       |       |
| Squat                      | 5       | 4               | 3.860 | 3.520 | 2.529 | 4.560 | 2.770 |
| Squat                      | 5       | 6               | 4.670 | 4.280 | 3.810 | 5.500 | 3.390 |
| Squat                      | 15      | 4               | 4.600 | 4.270 | 3.870 | 5.301 | 3.515 |
| Squat                      | 15      | 6               | 5.790 | 5.390 | 3.668 | 6.610 | 4.500 |
| Arm                        | 5       | 4               | 2.780 | 2.540 | 2.270 | 3.260 | 2.030 |
| Arm                        | 5       | 6               | 3.050 | 2.810 | 2.530 | 3.544 | 2.280 |
| Arm                        | 15      | 4               | 3.540 | 3.300 | 3.030 | 4.020 | 2.790 |
| Arm                        | 15      | 6               | 4.190 | 3.950 | 3.670 | 4.680 | 3.415 |
| Rest                       |         |                 | 2.140 | 1.930 | 1.690 | 2.570 | 1.470 |
| Measured (Kcal/min)        |         |                 |       |       |       |       |       |
| Squat                      | 5       | 4               | 4.710 | 2.963 | 2.903 | 4.058 | 3.200 |
| Squat                      | 5       | 6               | 6.410 | 4.195 | 3.664 | 5.215 | 3.288 |
| Squat                      | 15      | 4               | 4.655 | 4.758 | 4.075 | 4.691 | 3.225 |
| Squat                      | 15      | 6               | 7.323 | 5.588 | 5.198 | 5.823 | 3.780 |
| Arm                        | 5       | 4               | 3.828 | 3.950 | 2.527 | 2.976 | 1.795 |
| Arm                        | 5       | 6               | 3.750 | 3.208 | 2.263 | 3.395 | 2.113 |
| Arm                        | 15      | 4               | 4.688 | 3.573 | 3.572 | 3.993 | 3.920 |
| Arm                        | 15      | 6               | 5.403 | 5.500 | 4.067 | 5.004 | 3.545 |
| Rest                       |         |                 | 2.401 | 2.168 | 1.584 | 2.155 | 1.686 |
| MtM Prediction (Kcal/min)  |         |                 |       |       |       |       |       |
| Squat                      | 5       | 4               | 3.356 | 2.927 | 2.318 | 3.184 | 2.173 |
| Squat                      | 5       | 6               | 3.831 | 3.305 | 2.683 | 3.658 | 2.415 |
| Squat                      | 15      | 4               | 5.261 | 4.443 | 3.782 | 5.085 | 3.145 |
| Squat                      | 15      | 6               | 6.696 | 5.584 | 4.885 | 6.517 | 3.876 |
| Arm                        | 5       | 4               | 3.413 | 2.973 | 2.362 | 3.241 | 2.202 |
| Arm                        | 5       | 6               | 3.928 | 3.382 | 2.757 | 3.755 | 2.465 |
| Arm                        | 15      | 4               | 5.450 | 4.593 | 3.928 | 5.274 | 3.241 |
| Arm                        | 15      | 6               | 6.977 | 5.825 | 5.101 | 6.798 | 4.020 |
| Rest                       |         |                 | 2.401 | 2.168 | 1.584 | 2.231 | 1.686 |

in 40 observations for each method. Resting conditions were not included in the analysis of variance as load and frequency were not applicable. An analysis of variance was set up to test the null hypothesis that there is no difference in the mean steady-state predictions between the three methods. The three methods were the Garg prediction equations, the actual measures, and the systems model. The four remaining factors were lift type, load, lifting frequency and subject. Table 5 shows the data set used for the analysis of variance. The statistical model was analyzed on SAS (SAS System Version 5, SAS Institute Inc.) utilizing a SUN Sparc Station 2. The statistical model took the form of:

$$\begin{aligned}
 Y = & \text{MU} + \text{METHOD} + \text{A} + \text{B} + \text{C} + \text{D} + \text{METHOD}*\text{A} + \text{METHOD}*\text{B} + \\
 & \text{METHOD}*\text{C} + \text{METHOD}*\text{D} + \text{METHOD}*\text{A}*\text{B} + \text{METHOD}*\text{A}*\text{C} + \\
 & \text{METHOD}*\text{B}*\text{C} + \text{METHOD}*\text{A}*\text{B}*\text{C} + \text{A}*\text{B} + \text{A}*\text{C} + \text{A}*\text{D} + \text{A}*\text{B}*\text{C} + \text{B}*\text{C} \\
 & + \text{B}*\text{D} + \text{C}*\text{D} + \text{Error}
 \end{aligned} \tag{18}$$

Where: Y = Energy Metabolized (Kcal/min)

|                                            |        |
|--------------------------------------------|--------|
| METHOD = Modeling Method (MtM, Garg, Exp.) | Fixed  |
| A = Lift Type (Squat, Arm)                 | Fixed  |
| B = Load (5, 15 Kg)                        | Fixed  |
| C = Frequency (4, 6 lifts/min.)            | Fixed  |
| D = Subject (1-5)                          | Random |

Table 6 shows the results of the Analysis of Variance. Any null hypothesis was rejected if F was significantly greater than 1 at the .05 level. F was calculated using the estimated mean squared error. The analysis of variance

**Table 6.** Analysis of variance results.

| Source            | DF       | Sum of Squares | Mean Square   | F Value  | Significant |
|-------------------|----------|----------------|---------------|----------|-------------|
| Model             | 48       | 2031.53804717  | 42.32370932   | 350.23   | *           |
| Error             | 72       | 8.70087583     | 0.12084550    |          |             |
| Uncorrected Total | 120      | 2040.23892300  |               |          |             |
| R-Square          | C.V.     | Root MSE       | ENERGY Mean   |          |             |
| 0.948951          | 8.806608 | 0.34762839     | 3.94735833    |          |             |
| Source            | DF       | Type I SS      | Mean Square   | F Value  | Significant |
| MU                | 1        | 1869.79653741  | 1869.79653741 | 15472.62 |             |
| METHOD            | 2        | 2.33787432     | 1.16893716    | 2.06     |             |
| A                 | 1        | 11.29453521    | 11.29453521   | 39.95    | *           |
| METHOD*A          | 2        | 8.71116482     | 4.35558241    | 36.04    | *           |
| B                 | 1        | 53.65247601    | 53.65247601   | 330.24   | *           |
| METHOD*B          | 2        | 6.92586812     | 3.46293406    | 28.66    | *           |
| A*B               | 1        | 0.42257201     | 0.42257201    | 3.50     |             |
| METHOD*A*B        | 2        | 0.25131502     | 0.12565751    | 1.04     |             |
| C                 | 1        | 16.24425667    | 16.24425667   | 51.24    | *           |
| METHOD*C          | 2        | 0.09357875     | 0.04678937    | 0.39     |             |
| A*C               | 1        | 1.10572801     | 1.10572801    | 9.15     | *           |
| METHOD*A*C        | 2        | 0.88319552     | 0.44159776    | 3.65     | *           |
| B*C               | 1        | 1.98121301     | 1.98121301    | 16.39    |             |
| METHOD*B*C        | 2        | 0.47969282     | 0.23984641    | 1.98     |             |
| A*B*C             | 1        | 0.19853468     | 0.19853468    | 1.64     |             |
| METHOD*A*B*C      | 2        | 0.08211185     | 0.04105592    | 0.34     |             |
| D                 | 4        | 49.57902372    | 12.39475593   | 102.57   | *           |
| METHOD*D          | 8        | 4.53304543     | 0.56663068    | 4.69     | *           |
| A*D               | 4        | 1.13073208     | 0.28268302    | 2.34     |             |
| B*D               | 4        | 0.56475778     | 0.14118945    | 1.17     |             |
| C*D               | 4        | 1.26983395     | 0.31745849    | 2.63     |             |

showed that the F statistic was significantly greater than 1, at the 0.05 level of significance, between all main effects except the modeling method and some interactions. The significant differences between the factors were anticipated

and indicate that the experiment was conducted with sufficient resolution to expose the differences.

The modeling method was not significant. This indicates that both the MtM and the Garg model perform equally well at predicting the steady-state values for energy expenditure. Some of the interactions with the modeling method were found to be significant and were analyzed to determine the nature of the interaction.

These interactions were analyzed with a range test in a posthoc analysis. Table 7 shows the results of the range test. Figures 13-16 show the interactions graphically. The most obvious interaction can be seen in Figure 13. This is the

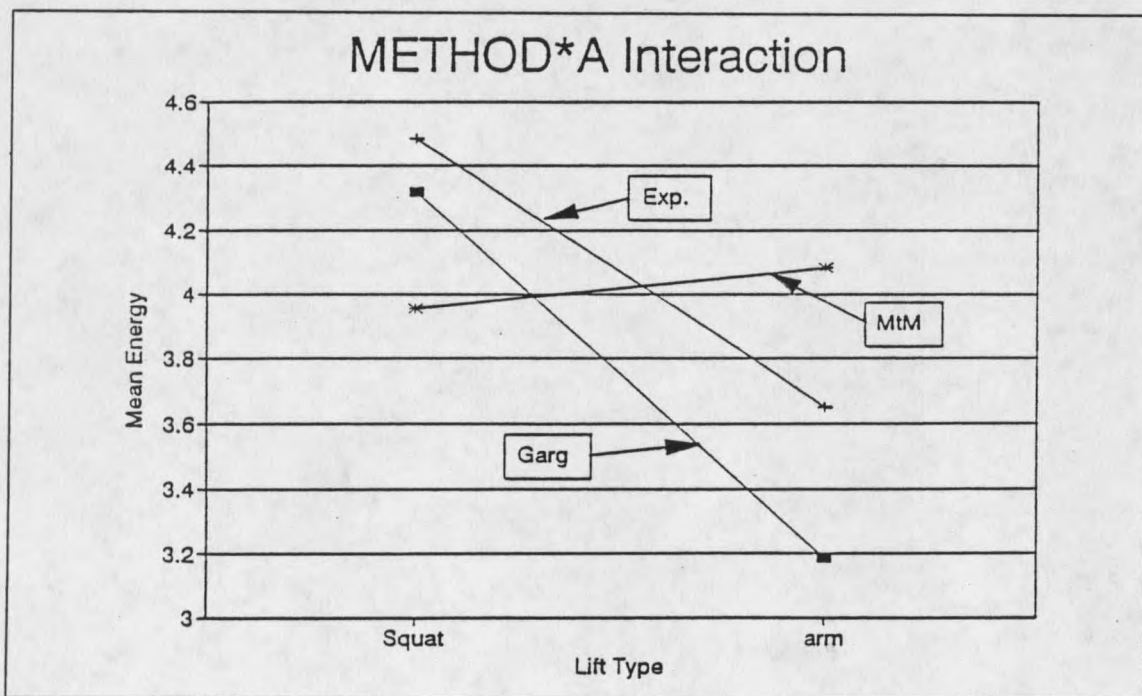


Figure 13. Interaction of modeling method and lifting type.



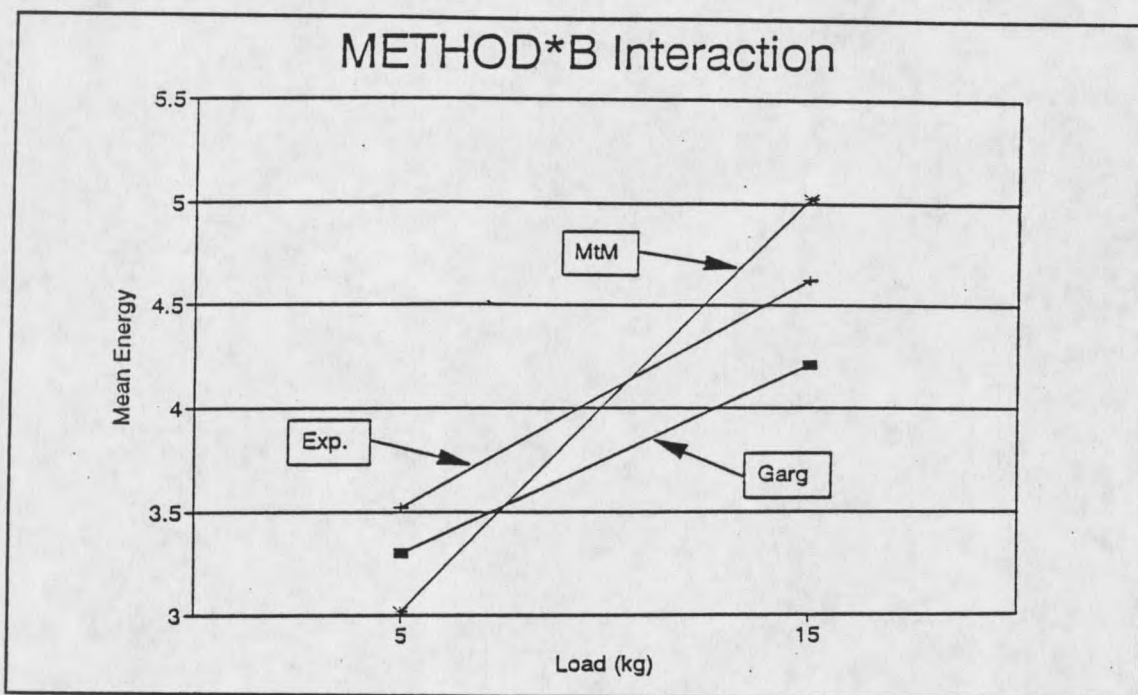


Figure 14. Interaction of modeling method and load.

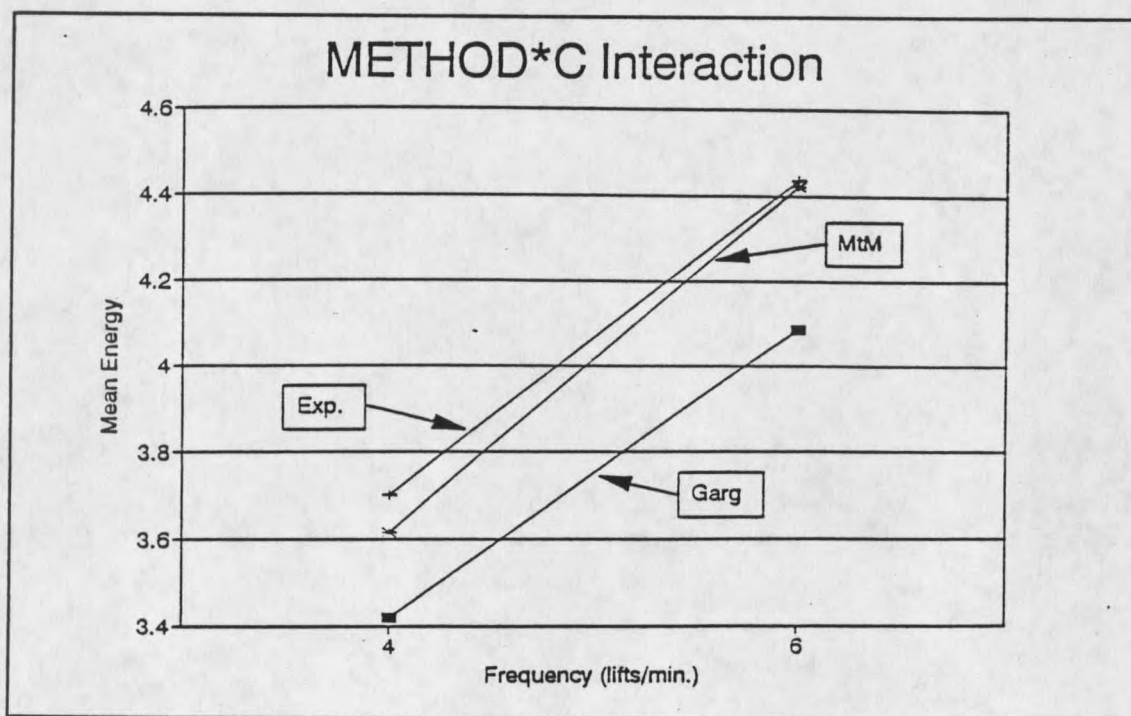


Figure 15. Interaction of modeling method and lifting frequency.

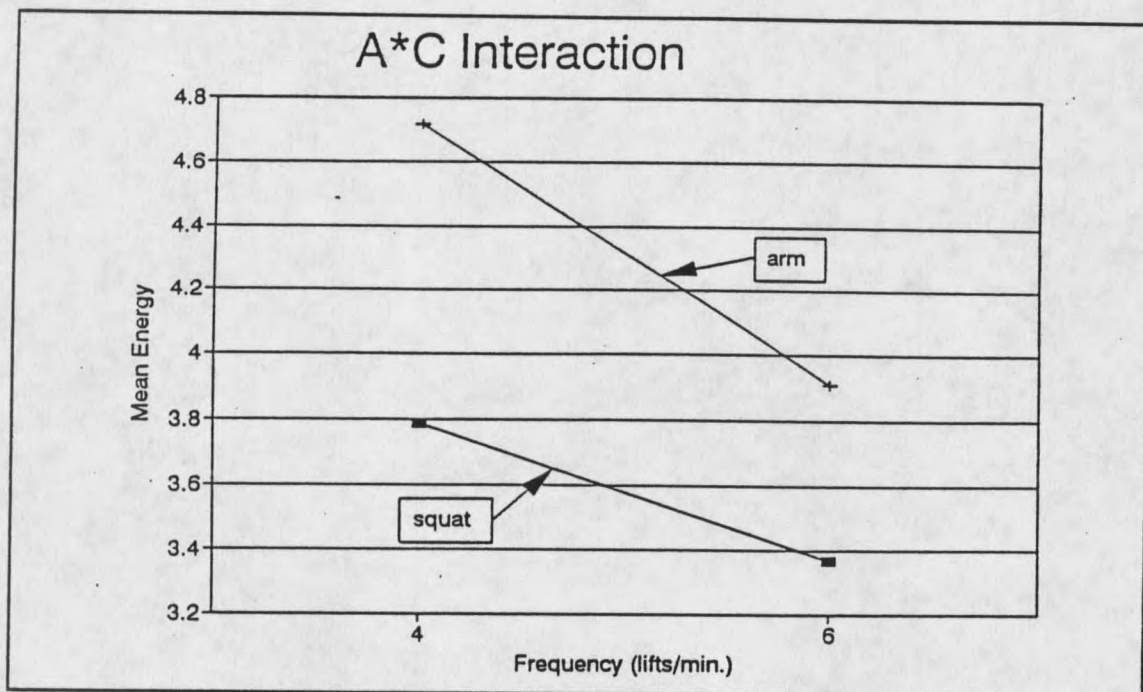


Figure 16. Interaction of lifting type and lifting frequency.

interaction of the factors METHOD and lifting type. Clearly one can see that the MtM model does not display the same interaction as the Garg and experimental data. The MtM model shows little interaction with respect to the type of lift where both the Garg and the actual measured data are quite sensitive to the type of lift. It is suspected that the physiological differences between the arm lifting task and the squat task were not articulated in the MtM model. It is expected that the Garg model shows the proper interaction relative to the experimental data as the Garg regression equations were derived from experimentation of similar task. The MtM model was calibrated based on cycle and arm ergometry. The resulting model is an extrapolation of the ergometry calibration to both of the lifting tasks.

It should be possible to calibrate the MtM model for a similar task and achieve the appropriate level of sensitivity. It is to the MtM model's advantage to be insensitive to minor interactions if the net effect of the system can be modeled accurately enough. The MtM model is hoped to be a more robust model capable of modeling a wider range of tasks with the same model form yet still be capable of more accurate model performance with accurate calibration for a specific task.

The dynamic performance of the model involved comparing the system's model and the Garg prediction equations ability to predict the actual measured values over time. The sum of the absolute difference, expressed as a percent of the total measured value, that was used for calibration served as a benchmark. A workload profile was created for each subject based on the actual random order in which data were collected. The workload was then processed by the model as exogenous data to produce a predicted oxygen consumption time series. Likewise, the Garg prediction equations were used to develop the estimated energy expenditure for each time period of the workload profile in Kcal/min. The predicted energy was then converted to an equivalent oxygen uptake rate using the same gain relationship that was used for the system model.

The resulting two time series were then compared to the actual oxygen uptake time series using the sum of the absolute difference. A small sample comparison of two means was conducted to compare the mean sum of the absolute difference between the system model and the Garg prediction



Table 7. Results from range tests conducted on the significant interactions.

| METHOD*A   | METHOD A |       | N  | Mean | SD   |      |
|------------|----------|-------|----|------|------|------|
|            | EXP      | Squat | 20 | 4.49 | 1.19 |      |
|            | GARG     | Squat | 20 | 4.32 | 1.03 |      |
|            | MtM      | Arm   | 20 | 4.08 | 1.41 |      |
|            | MtM      | Squat | 20 | 3.96 | 1.34 |      |
|            | EXP      | Arm   | 20 | 3.65 | 1.02 |      |
|            | GARG     | Arm   | 20 | 3.18 | 0.70 |      |
| METHOD*B   | METHOD B |       | N  | Mean | SD   |      |
|            | MtM      | 15    | 20 | 5.02 | 1.16 |      |
|            | EXP      | 15    | 20 | 4.62 | 1.00 |      |
|            | GARG     | 15    | 20 | 4.20 | 0.97 |      |
|            | EXP      | 5     | 20 | 3.52 | 1.09 |      |
|            | GARG     | 5     | 20 | 3.30 | 0.93 |      |
|            | MtM      | 5     | 20 | 3.02 | 0.57 |      |
| METHOD*C   | METHOD C |       | N  | Mean | SD   |      |
|            | EXP      | 6     | 20 | 4.44 | 1.37 |      |
|            | MtM      | 6     | 20 | 4.42 | 1.52 |      |
|            | GARG     | 6     | 20 | 4.09 | 1.12 |      |
|            | EXP      | 4     | 20 | 3.70 | 0.82 |      |
|            | MtM      | 4     | 20 | 3.62 | 1.07 |      |
|            | GARG     | 4     | 20 | 3.42 | 0.86 |      |
| A*C        | A        | C     | N  | Mean | SD   |      |
|            | Squat    | 6     | 30 | 4.72 | 1.29 |      |
|            | Arm      | 6     | 30 | 3.91 | 1.27 |      |
|            | Squat    | 4     | 30 | 3.79 | 0.89 |      |
|            | Arm      | 4     | 30 | 3.37 | 0.90 |      |
| METHOD*A*C | METHOD A | C     | N  | Mean | SD   |      |
|            | EXP      | Squat | 6  | 10   | 5.05 | 1.30 |
|            | GARG     | Squat | 6  | 10   | 4.76 | 1.04 |
|            | MtM      | Arm   | 6  | 10   | 4.50 | 1.60 |
|            | MtM      | Squat | 6  | 10   | 4.35 | 1.51 |
|            | EXP      | Squat | 4  | 10   | 3.92 | 0.78 |
|            | GARG     | Squat | 4  | 10   | 3.88 | 0.85 |
|            | EXP      | Arm   | 6  | 10   | 3.82 | 1.19 |
|            | MtM      | Arm   | 4  | 10   | 3.67 | 1.13 |
|            | MtM      | Squat | 4  | 10   | 3.57 | 1.07 |
|            | EXP      | Arm   | 4  | 10   | 3.48 | 0.84 |
|            | GARG     | Arm   | 6  | 10   | 3.41 | 0.76 |
|            | GARG     | Arm   | 4  | 10   | 2.96 | 0.60 |

**Table 8.** Comparison of both the Garg prediction equations and the MtM models' ability to predict the measured values dynamically using task 3 data.

---

| Subject | 1                                               | 2      | 3      | 4      | 5      | Ave.   | Stds. |
|---------|-------------------------------------------------|--------|--------|--------|--------|--------|-------|
| MtM     | 15.79%                                          | 13.34% | 17.70% | 17.84% | 15.57% | 16.05% | 1.84% |
| Garg    | 22.40%                                          | 20.27% | 19.04% | 19.67% | 22.02% | 20.68% | 1.47% |
| t       | = 4.39                                          |        |        |        |        |        |       |
| t crit. | = 1.86 (alpha = .05 and degrees of freedom = 8) |        |        |        |        |        |       |

---

equations. The null hypothesis was stated that there was no difference between these two means at the .05 level of significance for degrees of freedom of 8.

Table 8 contains the results of the comparison of mean percent differences. At the 0.05 level of significance, there was a significant difference between the modeling approaches. The system model was significantly better at predicting the oxygen uptake and/or energy expenditure under dynamic conditions than the Garg prediction equations.

Task 3 Observations. The major observation was with respect to model performance. The MtM and Garg models were not significantly different at predicting the steady-state level of the workload compared to the actual measured value. Each of the modeling methods were equally valid predictors for the task being modeled. It could be argued that the MtM systems model had an unfair advantage as model parameters were taken from the subject population and not from the general population at large. The Garg prediction equations were generated from a larger subject population and contain parameters that are more representative of the general population. Therefore, it is possible that the

reason the Garg prediction equations were significantly different from the measured values was due to the subject population being different from that used to generate the Garg prediction equations. This is to say that the subject populations for both this research and the Garg research were not significantly different from the population at large but they may be different from each other.

Nevertheless both models performed within reason. The most important conclusion that can be made is with respect to the MtM models' ability to predict the steady-state workload given proper model coefficients. Much work can be conducted in the future to develop better regression equations to predict the model coefficients.

Furthermore the system model had superior performance predicting dynamic conditions. This was expected as the systems model contains the functionality to describe the transient responses of the system where the Garg prediction equations do not have this ability. Being regression equations, the Garg prediction equations do not capture the transient response.

#### Task 4, Load Carrying

Data Preparation. The data were prepared in the same manner as for the previous tasks. The only change was with respect to the external work. Because the load does not change potential energy in a measurable manner during the task, the external work was taken as zero. The result was that no external work

was performed and the efficiency of the task was zero. This assumption implies that all energy in the system is manifested as heat production.

Model Use. In previous tasks, the model was driven by the time series derived from the measurable work done on the environment. For the carrying task, this is trivial as the external work time series is all non-existent. For this task, the model was altered to accept heart rate data as the driving data with oxygen uptake and heat production as solution variables.

Altering the form of the model to accommodate a change in exogenous input was accomplished with some minor revisions. The regression equation governing  $X_4$ , based on the level of  $X_6$  and  $X_7$ , was rewritten to base the rate of  $X_8$  on the levels of  $X_6$  and  $X_7$ . Note that there was a sign change in this regression equation due to the change in direction of the regression variable. No other equations were changed but some were rearranged where appropriate. Appendix E contains the model equations and matrix form used for task four.

Model Validation. By inspection (Appendix E) one can see that the Garg prediction equations are about 19% better at predicting oxygen uptake and/or energy production than the system model. A similar hypothesis test was conducted to compare the mean sum of the absolute error for both modeling methods as done in task 3. There was a significant difference in the error between the two models with the MtM systems model having the largest average

error. Table 9 contains the results of the comparison of mean percent differences. The MtM model had a dramatically larger sum of absolute difference. The Garg prediction equations are better predictors for task four.

**Table 9.** Comparison of both the Garg prediction equations and the MtM models' ability to predict the measured values dynamically using task 4 data.

---

| Subject | 1                                               | 2      | 3      | 4      | 5      | Avg.  | Stds. |
|---------|-------------------------------------------------|--------|--------|--------|--------|-------|-------|
| MtM     | 24.88%                                          | 66.48% | 31.83% | 35.03% | 50.21% | 42.0% | 16.7% |
| Garg    | 20.31%                                          | 18.55% | 35.20% | 22.20% | 20.49% | 23.0% | 6.7%  |
| t       | = 2.36                                          |        |        |        |        |       |       |
| t crit. | = 1.86 (alpha = .05 and degrees of freedom = 8) |        |        |        |        |       |       |

---

Task 4 Observations. The most obvious observation that can be made is the system model's poor ability to be driven from heart rate data. In case of a carrying task, where external work is difficult or impossible to measure, it is difficult to use heart rate data to predict oxygen uptake and/or energy production. Many factors control heart rate, especially at rest or with low workloads. Such factors must enter the model structure to achieve the objective of task four. Emotional stress, thermal stress, and noise factors may be modeled, given appropriate experimentation is conducted to quantify these effects.

Phase 2 Conclusions. Phase 2 demonstrated that the model performed as well as the Garg prediction equations for static, steady-state response, but yet

even better for dynamic response, given the model is driven by a known external workload. Conversely, the model did not perform as well as the Garg prediction equations when driven by actual measured heart rate data. This conclusion could be expected as several researchers have proposed models that regress total metabolic energy expenditure as a function of oxygen consumption, and/or externally measured parameters of the activity. Conversely, very few researchers have proposed models that include heart rate as a parameter. The implication for this study is that there are too many factors that affect heart rate to be modeled at the  $L_2$  level of detail.

### Phase 3, Combination Lifting

#### Test 5, Lifting and Carrying

Data Preparation. A workload profile was created by randomly selecting the number of lifts per minute, load, and duration of the task as well as the occurrence and length of a rest break. The workload profile was converted into an equivalent time series in Kcal per minute in a similar manner as for task 3. All other data were prepared in the same manner as for the previous tasks.

Model Use. The model solution was obtained using the pooled regression coefficients obtained from tasks 1 and 2. Appendix F contains the results of the model solution as well as the Garg model predictions. The structure of the

model was identical to that used for tasks one through three with external work as the driving exogenous data.

Observations and Conclusions. A hypothesis was constructed in a manner similar to task three, the system model was compared to the Garg prediction equations in dynamic prediction of the oxygen uptake. The systems model was significantly better, at the 0.05 level, than the Garg prediction equations. The test results, expressed in mean percent differences, can be seen in Table 10.

**Table 10.** Comparison of both the Garg prediction equations and the MtM models' ability to predict the measured values dynamically using task 5 data.

---

| Subject | 1                                               | 2      | 3      | 4      | 5      | Avg.  | Stds. |
|---------|-------------------------------------------------|--------|--------|--------|--------|-------|-------|
| MtM     | 13.48%                                          | 12.25% | 20.06% | 16.35% | 13.08% | 15.0% | 3.2%  |
| Garg    | 22.30%                                          | 19.85% | 18.61% | 26.31% | 19.56% | 21.3% | 3.1%  |
| t       | = 3.16                                          |        |        |        |        |       |       |
| t crit. | = 1.86 (alpha = .05 and degrees of freedom = 8) |        |        |        |        |       |       |

---

Given that much of task five involves a random workload profile that has very few steady-state regions, the system model should be superior based on Phase 2 experimentation. It can be concluded, based on Phase 3 testing, that the system model performed better at predicting physiological responses to the dynamic workload profile. For future analysis, workload profile can be substituted for a simulated workload profile, generated by Monte-Carlo random sampling, to conduct simulation experiments.



### Overall Observations of Model Comparisons

The examination of the MtM model's ability to converge on a steady-state value was shown in the analysis of variance conducted from task three data. One could argue that the model has the ability to converge on a steady-state value is a trivial feature. The true utility of the model stems from its ability to model the dynamic characteristics of human physiology and not only the steady-state characteristics. Figure 17 shows the mean percent error determined from tasks three through five for each modeling method. One can see that the Garg model converges on about 22% error for each task. The MtM model converges on about 16% error for task three and five and about 42% for task four.

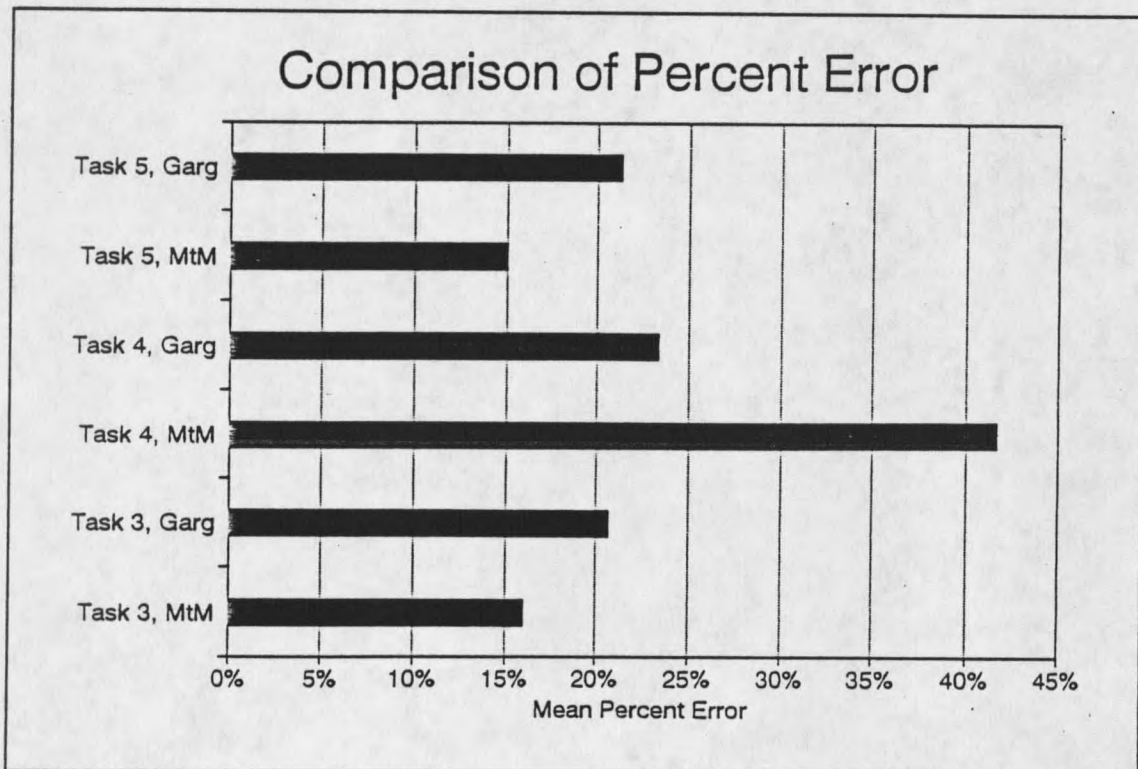


Figure 17. Comparison of mean modeling error.



The MtM model was constructed to allow for the external work done on the environment to drive the model for tasks three and five. The model was constructed to be driven from heart rate data for task 4. As shown previously, the MtM model performs better than the Garg model when driven from external workloads and performs poorly when driven by heart rate data. This observation implies that the MtM model does not fully describe the system at the level modeled. It is possible that the system is not modeled correctly. Given that the MtM model does display the appropriate system's responses when driven by external work it is more likely that the system is modeled correctly but the dynamics that govern heart rate are illuminated at level two.

Many factors affecting heart rate are not present in the model at level two. This limitation does not prevent the level two model from being useful but does limit its ability to be useful at utilizing heart rate data as a driving parameter.

## CHAPTER 6

### CONCLUSIONS

#### The Development of a Useful Physiological Model

The model as it is defined in this research may be adequate as a work design tool. The model predicts the same parameters as models currently in use. Furthermore, the model performed as well as a model that is widely used in work design. However, the range of subject population and tasks used in this research was narrow. Additional experimentation to determine better methods of obtaining model coefficients may be all that is necessary to make the model as robust and accurate as current models.

The model could be coded easily in a programming language as it only involves matrix math in conjunction with appropriate control on the model coefficients. One could develop an interface that allows the user to easily define the external workload profile. Parameters of the subject or population being modeled would also be easily inputted. Regression equations would convert the input into the appropriate model coefficients.

With the appropriate model coefficients defined and the external workload profile defined, the model would proceed to solve the set of linear equations for each time period. The algorithm would also check the workload profile to determine if the type of work such as leg lifting, arm lifting, and load carrying has changed. If a change in the type of work is encountered the appropriate model coefficients would be changed, the matrix inverted and the solution continued for each time period until a change is encountered again.

Additional benefit could be obtained by allowing the definition of the external workload profile to be specific parameters of the environment. Such parameters would include the type of lift, the starting height, the ending height, and the frequency.

Simulation style experiments could be conducted by allowing the external workload to be specified by a random process. These experiments could be conducted based on individual or population parameters. Statistics could then be collected to determine the probability of exceeding acceptable limits.

Full Level Two model expansion will allow for the inclusion of parameters such as diet and heat transfer modes. The inclusion of diet would provide for simulation experiments based on individual and population parameters. Similar to the above discussion, the additional parameters will allow simulation experiments with changes in worker diet and thermal environment. Probably more important than nutrient digestion will be the inclusion of external

parameters such as temperature, humidity, and clothing. A work designer will have more control over thermal environmental conditions than a worker's diet.

### Additional Experimentation

#### Sensitivity Analysis

Future research should include examination for sensitivity of the model coefficients. More specifically, the coefficients for net metabolic yield, efficiency, resting metabolism, and the regression coefficients for oxygen consumption as a function of heart rate should be analyzed. All of these coefficients were treated as individual parameters of the subjects in this study. It is possible that most, if not all, of the individual parameters could be substituted by population parameters even though contrary conclusions were made in this research.

A series of experiments could be conducted to test the sensitivity of each of the parameters. Several repetitions of the same task should be conducted for each subject. The model should then be solved with parameters developed for individuals as well as for population parameters.

An analysis of variance could then be conducted to determine which of the parameters significantly influence the response of the model. Of the parameters that significantly influence response, one could determine if that parameter varies significantly between individuals.

Based on the above, one could develop prediction equations for determining the parameters that are appropriate and/or determine what level of error can reasonably be expected. It is possible that some of the parameters are influenced by "noise" while others are not.

To become a useable tool for conducting work design, a general calibration procedure will need to be developed and tested. The model could operate at prescribed levels of accuracy depending on the requirements of the modeling task.

### Regression Analysis

The model as it is defined in this thesis is highly sensitive to several model coefficients. The most sensitive coefficient is the net metabolic yield. The least sensitive are the transient response coefficients. In the future it will be necessary to quantify the sensitivity of the model to the coefficients. In this thesis the coefficients were determined through experimentation for each individual. To become a useful tool in the future these coefficients will need to be determined from regression equations based on such inputs as body mass, age, physical condition, and anthropometric measures.

A series of experiments could be conducted to determine the required regression equations. Coefficients that the model is not sensitive to will be robust in nature with a liberal regression equation that will yield adequate

parameters for a wide range of inputs. Coefficients that the model is sensitive to will require regression equations constructed to yield more accurate coefficients.

It may be possible to repeat the experiments in this thesis with a larger and more diverse population. A factor analysis could then be conducted to determine what factors significantly affect the model's performance. Regression equations for coefficient values could then be developed that have the significant factors as input to the equations.

### Validation Testing

Before the model can be implemented as a useful work design tool, more thorough validation testing will need to be accomplished. The clinical testing conducted in this thesis as well as the clinical testing mentioned above focus on short duration tasks that can be easily reproduced under controlled lab conditions. True validation testing will necessarily involve long duration testing with actual industrial tasks.

A range of industrial tasks should be chosen that involve large rhythmic muscle movements. Lifting and carrying tasks, such as those used in this thesis, would serve the purpose. The worker should be allowed to conduct a long duration task with the normal work rest cycles of the task. Similar data should be collected as was collected in this thesis. The tasks should be analyzed with motion analysis to categorize the time into the appropriate type of motion so appropriate model coefficients can be assessed for that period of time.

Additionally, the motion analysis should yield an estimate of the approximate external work conducted.

The goal of the experimentation should be to determine adequacy of model performance in a similar manner as done in this research. An additional goal should be to determine if the model performs adequately when heart rate data is used as the exogenous data set.

It is suspected that the short duration tasks chosen for this research were simply too short to smooth the effect of the variability inherent in heart rate data. Long duration tasks may provide a large enough population of heart rate data to be adequate for predicting oxygen consumption and net metabolic energy production.

By far the most powerful aspect of the model will be the ability to use heart rate data to make reasonable predictions of the other model parameters. Because heart rate data is much easier and less expensive to obtain, work designers can use the model to conduct simulation style experiments, worker screening, and monitoring for the purpose of insuring the worker does not exceed safe limits. The results of this research were inconclusive if using purely heart rate data. With better methods for determining the model coefficients and longer duration tasks it may be possible in the future.

## Model Expansion

### Level Two Expansion

Heat Transfer Modes. Heat transfer modes are the next logical expansion of the model. The scope of the modeling for this thesis was restricted to heat existing only at the instance it is created during the metabolic reaction. It is very well known that the heat produced from the metabolic reaction undergoes storage and delay as it is transported out of the body. The relevant heat transfer modes such as conduction, convection, evaporation, etc., could be modeled easily with the appropriate addition of subsystems.

A greater challenge would be to parameterize the subsystems. Such parameters as net thermal conductivity of the body, surface area of the body, and net convective heat transfer coefficient of the skin would need to be estimated. These parameters could be estimated from previous research and validated with experimentation.

Experimentation would necessarily involve equipment capable of measuring body core and average temperatures, and total heat transferred to the environment. This experimentation, although feasible, would not be trivial.

Great benefits could be achieved with the inclusion of the heat transfer modes. Environmental factors such as air temperature, humidity, and clothing would enter the model. In a similar manner as previously described for this research, simulation style experiments could be conducted with the model to



determine if all or a portion of the population is at risk of a thermal imbalance. This thermal imbalance could be as a result of a lowering or increasing of body core temperature beyond normal limits.

Nutrient Digestion. After the heat transfer modes, the next logical expansion of the model would be nutrient digestion. Nutrients that enter the body through the mouth experience the dynamics of transportation, storage, and delay as they are converted and made available for metabolism with oxygen. One could diagram the appropriate subsystems for the digestive path of each nutrient source. Again, parameterization would not be trivial. One would need to model each of the chemical reactions involved in the intermediate metabolism.

The model as it is specified in this thesis is under specified. A complete specification of the model will only be achieved if the nutrient portion of the system is included. The transportation and digestion of nutrients require energy. This energy is manifested as heat production eventually.

### Level Three Expansion

Aerobic and Anaerobic metabolism. For the model to distinguish between aerobic and anaerobic metabolism, one will necessarily need to take the model to level three. The model, as it is described in this research, describes the net metabolic reaction. The model assumes one form of the net metabolic reaction by assigning a net metabolic yield for one unit of oxygen equal to a specific

number of units of energy. The net metabolic gain will necessarily be different for aerobic and anaerobic metabolism.

The model will need to have the ability to automatically adjust for the changes in metabolism. The body is undergoing anaerobic metabolism all the time. The amount of energy metabolized via anaerobic metabolism is mostly related to the availability of oxygen and various nutrients. As the body depletes its supply of oxygen, anaerobic metabolism grows significantly to supply the energy to sustain the workload. Because of this relationship between the level of available oxygen in the body and the amount of anaerobic metabolism, it may be possible to regress the amount of anaerobic metabolism based on the level of oxygen stored in the body.

The level of oxygen is not the only determining factor of which type of metabolism is being conducted. The nutrient levels in the body are also factors. Also for aerobic metabolism, there exists unique gain relationships for each type of nutrient being metabolized with oxygen. Due to the complicated interactions involved in determining the level of anaerobic metabolism one should fully expand the Level Two model to include nutrient digestion.

A possible model formulation could involve a subsystem for each nutrient type as well as those for oxygen. A metabolic gain relationship could be defined for pertinent metabolic reaction. Regression equations would then need to be defined as a control mechanism to determine the relative amount of oxygen each metabolic relationship is allowed to metabolize as well as the level of anaerobic

metabolism. The balance equation would tie all the metabolism relationships together to insure the level of external and internal energy is equal to the level metabolized.

The above is not a trivial task. Furthermore, little gain in developing a useful work design tool will be accomplished. The above will have possible merit for medical applications.

A complicating factor in conducting this level three model development will be in model validation. Experimentation will necessarily involve invasive techniques to determine the metabolic profile over time.

Differentiation of Blood Flow. The differentiation of blood flow, it is suspected, would yield little benefit to the development of a useful work design tool. The benefit to differentiating of blood flow may yield benefit to medical research.

Subsystems for blood flow from the heart to large body areas, such as the legs, arms, head, and torso, could be specified. Similar transient response coefficients for the blood flow through the new subsystems would describe the transportation, delay, and storage of blood in the respective region supplied by the subsystem. These parameters may be useful in determining the flow of toxins, nutrients, and medications through the subsystem.

It is also possible that understanding the dynamics of the system as it is modeled at Level Three may yield a model that has superior performance at

predicting dynamic workloads. Specifically the model may have the ability to more accurately distinguish the net metabolic workload for arm versus leg workloads.

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## APPENDICES

## APPENDIX A

### General

## Consent Form

You are invited to participate in a study using quantitative methods to determine physical work capacity. It is anticipated that the results of this study will aid managers and engineers in conducting better work design. If you decide to participate, you will be required to complete a questionnaire regarding your medical history. You will be required to participate in several experiments requiring physical exertion.

Your participation is completely voluntary. You may choose to withdraw from participation at any time. All information obtained during this study by which you could be identified will be held in strict confidence.

If at any time you have questions regarding this research you may contact:

Rob Wehrman  
402 Roberts Hall  
Bozeman, MT 59714  
(406) 994-3812

By signing below you are indicating that you have read all the above information, are willing to participate, and free the conductors of this study from any liabilities that may incur.

Signature of participant

Date

Rob Wehrman  
Investigator

Date

## Subject Screening Questionnaire

Name:

Date:

Please give name and phone number of person to be contacted in case of an emergency:

Name and phone number of physician and physician's hospital:

Please circle if susceptible to:

Shortness of breath

Dizziness

Head aches

Fatigue

Pain in arm, shoulder, or chest

If so, explain:

Are you currently taking any type of medication?

If so, explain:

Have you had or do you now have any problems with your blood pressure?

If so, explain:

Within the last six months, have you had any type of surgery or serious illness?

If so, explain:

Within the last six months, have you had any type of back pain, particularly in the lower back?

If so, explain:

Have you ever had or do you now have a hernia?

If so, corrective date:

Have you had your normal amount of sleep within the past 24 hours?

Have you had your normal amount of food within the past 24 hours?

## Initial Subject Data Collection Form

Name:

Gender:

Age:

Height:

Weight:

Knuckle Height:

Shoulder Height:

Physical Condition:

Resting heart rate:

Resting blood pressure:

## Experiment Data Collection Form

### Data Collection Form

Name:  
 Time and date:  
 File name:  
 Experiment type:  
 Resting HR:  
 Resting BP:  
 Wet bulb temp.:  
 Dry bulb temp.:  
 Humidity:  
 Lifts/min.:  
 Weight:

Notes:

| Time | Work loa | HR | Time |
|------|----------|----|------|
| 1    |          |    | 1    |
| 2    |          |    | 2    |
| 3    |          |    | 3    |
| 4    |          |    | 4    |
| 5    |          |    | 5    |
| 6    |          |    | 6    |
| 7    |          |    | 7    |
| 8    |          |    | 8    |
| 9    |          |    | 9    |
| 10   |          |    | 10   |
| 11   |          |    | 11   |
| 12   |          |    | 12   |
| 13   |          |    | 13   |
| 14   |          |    | 14   |
| 15   |          |    | 15   |
| 16   |          |    | 16   |
| 17   |          |    | 17   |
| 18   |          |    | 18   |
| 19   |          |    | 19   |
| 20   |          |    | 20   |
| 21   |          |    | 21   |
| 22   |          |    | 22   |
| 23   |          |    | 23   |
| 24   |          |    | 24   |
| 25   |          |    | 25   |
| 26   |          |    | 26   |
| 27   |          |    | 27   |
| 28   |          |    | 28   |
| 29   |          |    | 29   |
| 30   |          |    | 30   |

## APPENDIX B

### Task 1 Data

Subject 1, Task 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|---------|
| 0.5                  | 0                     | 0.0000           | 103                 | 0.7500               | 1.2420               | 4.7658          | 5.9191          | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 100                 | 0.7900               | 1.1840               | 4.8191          | 5.7058          | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 100                 | 0.7700               | 0.9880               | 4.7924          | 4.7349          | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 101                 | 0.7600               | 1.0550               | 4.7791          | 5.0419          | 0.0000  |
| 2.5                  | 60                    | 0.8598           | 111                 | 0.7600               | 0.9420               | 4.7791          | 4.5019          | -0.5747 |
| 3.0                  | 60                    | 0.8598           | 116                 | 0.7300               | 1.3960               | 4.7391          | 6.6158          | 1.3917  |
| 3.5                  | 60                    | 0.8598           | 116                 | 0.7200               | 1.7400               | 4.7258          | 8.2228          | 0.3865  |
| 4.0                  | 60                    | 0.8598           | 119                 | 0.7400               | 1.6910               | 4.7524          | 8.0363          | 0.4218  |
| 4.5                  | 60                    | 0.8598           | 117                 | 0.7500               | 1.6780               | 4.7658          | 7.9969          | 0.4301  |
| 5.0                  | 60                    | 0.8598           | 116                 | 0.7400               | 1.6070               | 4.7524          | 7.6371          | 0.5245  |
| 5.5                  | 60                    | 0.8598           | 115                 | 0.7700               | 1.8730               | 4.7924          | 8.9762          | 0.2887  |
| 6.0                  | 60                    | 0.8598           | 118                 | 0.7900               | 1.7380               | 4.8191          | 8.3755          | 0.3616  |
| 6.5                  | 60                    | 0.8598           | 115                 | 0.8200               | 1.7420               | 4.8591          | 8.4645          | 0.3486  |
| 7.0                  | 60                    | 0.8598           | 117                 | 0.8000               | 1.6330               | 4.8324          | 7.8913          | 0.4541  |
| 7.5                  | 100                   | 1.4330           | 127                 | 0.8100               | 1.8450               | 4.8457          | 8.9404          | 0.6048  |
| 8.0                  | 100                   | 1.4330           | 126                 | 0.8200               | 2.0140               | 4.8591          | 9.7861          | 0.4457  |
| 8.5                  | 100                   | 1.4330           | 132                 | 0.8200               | 2.1370               | 4.8591          | 10.3838         | 0.3759  |
| 9.0                  | 100                   | 1.4330           | 131                 | 0.8400               | 2.0360               | 4.8857          | 9.9473          | 0.4244  |
| 9.5                  | 100                   | 1.4330           | 130                 | 0.8600               | 2.2540               | 4.9124          | 11.0725         | 0.3183  |
| 10.0                 | 100                   | 1.4330           | 132                 | 0.8600               | 2.3220               | 4.9124          | 11.4065         | 0.2964  |
| 10.5                 | 100                   | 1.4330           | 131                 | 0.8800               | 2.2980               | 4.9390          | 11.3499         | 0.2999  |
| 11.0                 | 100                   | 1.4330           | 134                 | 0.8600               | 2.1970               | 4.9124          | 10.7925         | 0.3395  |
| 11.5                 | 150                   | 2.1495           | 140                 | 0.8700               | 2.3180               | 4.9257          | 11.4178         | 0.5204  |
| 12.0                 | 150                   | 2.1495           | 146                 | 0.8500               | 2.5980               | 4.8991          | 12.7277         | 0.3951  |
| 12.5                 | 150                   | 2.1495           | 148                 | 0.8700               | 2.7370               | 4.9257          | 13.4817         | 0.3470  |
| 13.0                 | 150                   | 2.1495           | 151                 | 0.9000               | 2.8380               | 4.9657          | 14.0927         | 0.3159  |
| 13.5                 | 150                   | 2.1495           | 151                 | 0.9200               | 2.9090               | 4.9924          | 14.5228         | 0.2971  |
| 14.0                 | 150                   | 2.1495           | 151                 | 0.9200               | 2.8950               | 4.9924          | 14.4529         | 0.3000  |
| 14.5                 | 150                   | 2.1495           | 152                 | 0.9100               | 3.0810               | 4.9790          | 15.3404         | 0.2669  |
| 15.0                 | 150                   | 2.1495           | 153                 | 0.9300               | 3.0550               | 5.0057          | 15.2924         | 0.2685  |
| 15.5                 | 0                     | 0.0000           | 132                 | 0.9300               | 2.6680               | 5.0057          | 13.3552         | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 130                 | 1.0200               | 2.0250               | 5.1257          | 10.3795         | 0.0000  |
| 16.5                 | 0                     | 0.0000           | 119                 | 1.1600               | 1.4030               | 5.3123          | 7.4531          | 0.0000  |
| 17.0                 | 0                     | 0.0000           | 116                 | 1.1100               | 1.2690               | 5.2456          | 6.6567          | 0.0000  |
| 17.5                 | 0                     | 0.0000           | 108                 | 1.0100               | 1.1310               | 5.1123          | 5.7820          | 0.0000  |
| 18.0                 | 0                     | 0.0000           | 106                 | 0.9800               | 0.9130               | 5.0723          | 4.6310          | 0.0000  |
| 18.5                 | 0                     | 0.0000           | 107                 | 0.9300               | 0.9990               | 5.0057          | 5.0007          | 0.0000  |
| 19.0                 | 0                     | 0.0000           | 107                 | 0.9300               | 0.8570               | 5.0057          | 4.2899          | 0.0000  |



Subject 1, Task 1, PWC calculation

| Work Load | HR     | VO2   |
|-----------|--------|-------|
|           | X      | Y     |
| 1         | 116.25 | 1.747 |
| 2         | 131.75 | 2.268 |
| 3         | 151.75 | 2.985 |

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | -2.31969 |
| Std Err of Y Est    | 0.015908 |
| R Squared           | 0.999673 |
| No. of Observations | 3        |
| Degrees of Freedom  | 1        |

|                  |            |
|------------------|------------|
| X Coefficient(s) | 0.03491949 |
| Std Err of Coef. | 0.00063203 |

Max. HR            194

PWC                4.4546926

## Subject 1, Test 1

| Equation Type           | Equation                                    | Equation Parameters |        |             |
|-------------------------|---------------------------------------------|---------------------|--------|-------------|
| regression<br>i/t       | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.42   | alfa= 0.61  |
| balance                 | $X1 + X2 = X3 + X4$                         |                     |        |             |
| regression              | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.79   | alfa= 0.10  |
| gain<br>i/t             | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0316 | C = -2.0825 |
| balance                 | $X4 + X6 = X7 + X8$                         |                     |        |             |
| gain                    | $X9 = Y * X8$                               | Y =                 | 4.9573 |             |
| balance                 | $X9 = X10 + X11 + X12$                      |                     |        |             |
| exogenous<br>regression | $X10 = \text{Eff} * X11$                    | Eff =               | 0.3314 |             |
| exogenous               | $X12 = \text{RM}$                           | RM =                | 5.1382 |             |

|   |        |        |    |        |        |        |       |    |    |       |   |   |     |   |        |     |
|---|--------|--------|----|--------|--------|--------|-------|----|----|-------|---|---|-----|---|--------|-----|
| 1 | 1.4524 | 0.9286 | 0  | 0      | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0      |     |
| 0 | 1      | 0      | 0  | 0      | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.94  | i/t |
| 1 | 1      | -1     | -1 | 0      | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0      |     |
| 0 | 0      | 0      | 1  | 0      | 0.1266 | 1.1392 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0      |     |
| 0 | 0      | 0      | -1 | 0.0316 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 2.0825 |     |
| 0 | 0      | 0      | 0  | 0      | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.96  | i/t |
| 0 | 0      | 0      | 1  | 0      | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0      | 0      | 0      | 4.957 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0      | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0      | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0      | ex  |
| 0 | 0      | 0      | 0  | 0      | 0      | 0      | 0     | 0  | -1 | 0.331 | 0 | 0 | X11 | = | 0      |     |
| 0 | 0      | 0      | 0  | 0      | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 1 | X12 | = | 5.1382 |     |

Subject 1, Task 1, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9    | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|-------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 |
| 0.00  | 1.70 | -0.94 | -0.36 | 1.12 | 101.35 | -0.96 | -0.88 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 1.00  | 0.96 | -0.36 | -0.47 | 1.07 | 99.78  | -0.88 | -0.84 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 2.00  | 1.09 | -0.47 | -0.43 | 1.05 | 99.14  | -0.84 | -0.83 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 3.00  | 1.22 | -0.43 | -0.63 | 1.41 | 110.63 | -0.83 | -1.15 | 1.73 | 8.59  | 0.86 | 2.59 | 5.14 |
| 4.00  | 1.55 | -0.63 | -0.68 | 1.60 | 116.62 | -1.15 | -1.28 | 1.73 | 8.59  | 0.86 | 2.59 | 5.14 |
| 5.00  | 1.65 | -0.68 | -0.71 | 1.68 | 119.06 | -1.28 | -1.33 | 1.73 | 8.59  | 0.86 | 2.59 | 5.14 |
| 6.00  | 1.70 | -0.71 | -0.72 | 1.71 | 120.06 | -1.33 | -1.35 | 1.73 | 8.59  | 0.86 | 2.59 | 5.14 |
| 7.00  | 1.72 | -0.72 | -0.73 | 1.72 | 120.47 | -1.35 | -1.36 | 1.73 | 8.59  | 0.86 | 2.59 | 5.14 |
| 8.00  | 1.85 | -0.73 | -0.86 | 1.98 | 128.47 | -1.36 | -1.58 | 2.20 | 10.90 | 1.43 | 4.32 | 5.14 |
| 9.00  | 2.07 | -0.86 | -0.89 | 2.11 | 132.60 | -1.58 | -1.67 | 2.20 | 10.90 | 1.43 | 4.32 | 5.14 |
| 10.00 | 2.14 | -0.89 | -0.91 | 2.16 | 134.29 | -1.67 | -1.71 | 2.20 | 10.90 | 1.43 | 4.32 | 5.14 |
| 11.00 | 2.18 | -0.91 | -0.92 | 2.18 | 134.98 | -1.71 | -1.73 | 2.20 | 10.90 | 1.43 | 4.32 | 5.14 |
| 12.00 | 2.34 | -0.92 | -1.08 | 2.50 | 145.04 | -1.73 | -2.00 | 2.78 | 13.77 | 2.15 | 6.49 | 5.14 |
| 13.00 | 2.62 | -1.08 | -1.13 | 2.67 | 150.24 | -2.00 | -2.12 | 2.78 | 13.77 | 2.15 | 6.49 | 5.14 |
| 14.00 | 2.71 | -1.13 | -1.15 | 2.73 | 152.36 | -2.12 | -2.16 | 2.78 | 13.77 | 2.15 | 6.49 | 5.14 |
| 15.00 | 2.75 | -1.15 | -1.16 | 2.76 | 153.23 | -2.16 | -2.18 | 2.78 | 13.77 | 2.15 | 6.49 | 5.14 |
| 16.00 | 2.32 | -1.16 | -0.68 | 1.84 | 124.23 | -2.18 | -1.38 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 17.00 | 1.50 | -0.68 | -0.55 | 1.37 | 109.12 | -1.38 | -1.05 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 18.00 | 1.24 | -0.55 | -0.48 | 1.17 | 102.96 | -1.05 | -0.91 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |
| 19.00 | 1.12 | -0.48 | -0.45 | 1.09 | 100.44 | -0.91 | -0.86 | 1.04 | 5.14  | 0.00 | 0.00 | 5.14 |

Subject 2, Task 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 79                  | 0.7600                                        | 0.2580                           | 4.7791          | 1.2330                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 77                  | 0.7900                                        | 0.1870                           | 4.8191          | 0.9012                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 74                  | 0.8200                                        | 0.2010                           | 4.8591          | 0.9767                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 76                  | 0.8100                                        | 0.1440                           | 4.8457          | 0.6978                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 77                  | 0.7900                                        | 0.1750                           | 4.8191          | 0.8433                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 77                  | 0.8000                                        | 0.1990                           | 4.8324          | 0.9616                      | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 79                  | 0.7700                                        | 0.2010                           | 4.7924          | 0.9633                      | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 81                  | 0.7600                                        | 0.1860                           | 4.7791          | 0.8889                      | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 79                  | 0.7600                                        | 0.2130                           | 4.7791          | 1.0179                      | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 77                  | 0.7900                                        | 0.2230                           | 4.8191          | 1.0747                      | 0.0000 |
| 5.5                  | 60                    | 0.8598           | 99                  | 0.7800                                        | 0.4990                           | 4.8057          | 2.3981                      | 2.1366 |
| 6.0                  | 60                    | 0.8598           | 96                  | 0.7300                                        | 0.7550                           | 4.7391          | 3.5780                      | 0.5434 |
| 6.5                  | 60                    | 0.8598           | 99                  | 0.7200                                        | 0.9220                           | 4.7258          | 4.3572                      | 0.3641 |
| 7.0                  | 60                    | 0.8598           | 102                 | 0.7600                                        | 0.9240                           | 4.7791          | 4.4159                      | 0.3553 |
| 7.5                  | 60                    | 0.8598           | 99                  | 0.7800                                        | 0.9240                           | 4.8057          | 4.4405                      | 0.3517 |
| 8.0                  | 60                    | 0.8598           | 100                 | 0.8000                                        | 0.9500                           | 4.8324          | 4.5908                      | 0.3313 |
| 8.5                  | 60                    | 0.8598           | 99                  | 0.8400                                        | 1.0220                           | 4.8857          | 4.9932                      | 0.2868 |
| 9.0                  | 60                    | 0.8598           | 97                  | 0.8400                                        | 0.9100                           | 4.8857          | 4.4460                      | 0.3509 |
| 9.5                  | 90                    | 1.2897           | 106                 | 0.8500                                        | 1.0150                           | 4.8991          | 4.9725                      | 0.5064 |
| 10.0                 | 90                    | 1.2897           | 106                 | 0.8800                                        | 1.1510                           | 4.9390          | 5.6848                      | 0.3957 |
| 10.5                 | 90                    | 1.2897           | 108                 | 0.9200                                        | 1.1710                           | 4.9924          | 5.8461                      | 0.3771 |
| 11.0                 | 90                    | 1.2897           | 111                 | 0.9200                                        | 1.1990                           | 4.9924          | 5.9858                      | 0.3622 |
| 11.5                 | 90                    | 1.2897           | 113                 | 0.9500                                        | 1.3790                           | 5.0324          | 6.9396                      | 0.2857 |
| 12.0                 | 90                    | 1.2897           | 112                 | 0.9600                                        | 1.3370                           | 5.0457          | 6.7461                      | 0.2985 |
| 12.5                 | 90                    | 1.2897           | 113                 | 0.9700                                        | 1.3010                           | 5.0590          | 6.5818                      | 0.3103 |
| 13.0                 | 90                    | 1.2897           | 113                 | 0.9700                                        | 1.3400                           | 5.0590          | 6.7791                      | 0.2962 |
| 13.5                 | 90                    | 1.2897           | 115                 | 0.9700                                        | 1.3200                           | 5.0590          | 6.6779                      | 0.3033 |
| 14.0                 | 90                    | 1.2897           | 113                 | 0.9400                                        | 1.3290                           | 5.0190          | 6.6703                      | 0.3038 |
| 14.5                 | 140                   | 2.0062           | 123                 | 0.9700                                        | 1.4100                           | 5.0590          | 7.1332                      | 0.5027 |
| 15.0                 | 140                   | 2.0062           | 123                 | 0.9500                                        | 1.5440                           | 5.0324          | 7.7699                      | 0.4335 |
| 15.5                 | 140                   | 2.0062           | 130                 | 0.9600                                        | 1.5000                           | 5.0457          | 7.5685                      | 0.4532 |
| 16.0                 | 140                   | 2.0062           | 131                 | 0.9800                                        | 1.7950                           | 5.0723          | 9.1049                      | 0.3365 |
| 16.5                 | 140                   | 2.0062           | 133                 | 1.0200                                        | 1.9210                           | 5.1257          | 9.8464                      | 0.2992 |
| 17.0                 | 140                   | 2.0062           | 132                 | 1.0100                                        | 1.8900                           | 5.1123          | 9.6623                      | 0.3077 |
| 17.5                 | 140                   | 2.0062           | 132                 | 1.0000                                        | 1.9120                           | 5.0990          | 9.7493                      | 0.3036 |
| 18.0                 | 140                   | 2.0062           | 132                 | 0.9900                                        | 1.9060                           | 5.0857          | 9.6933                      | 0.3062 |
| 18.5                 | 140                   | 2.0062           | 134                 | 0.9900                                        | 1.9630                           | 5.0857          | 9.9832                      | 0.2933 |
| 19.0                 | 140                   | 2.0062           | 134                 | 0.9900                                        | 2.0190                           | 5.0857          | 10.2680                     | 0.2815 |
| 19.5                 | 0                     | 0.0000           | 113                 | 0.9500                                        | 1.5360                           | 5.0324          | 7.7297                      | 0.0000 |
| 20.0                 | 0                     | 0.0000           | 96                  | 1.1500                                        | 1.0340                           | 5.2990          | 5.4791                      | 0.0000 |
| 20.5                 | 0                     | 0.0000           | 89                  | 1.3300                                        | 0.6650                           | 5.5389          | 3.6834                      | 0.0000 |
| 21.0                 | 0                     | 0.0000           | 82                  | 1.3400                                        | 0.4360                           | 5.5522          | 2.4208                      | 0.0000 |
| 21.5                 | 0                     | 0.0000           | 84                  | 1.2700                                        | 0.3670                           | 5.4589          | 2.0034                      | 0.0000 |
| 22.0                 | 0                     | 0.0000           | 79                  | 1.2000                                        | 0.2900                           | 5.3656          | 1.5560                      | 0.0000 |
| 22.5                 | 0                     | 0.0000           | 78                  | 1.1200                                        | 0.3010                           | 5.2590          | 1.5829                      | 0.0000 |
| 23.0                 | 0                     | 0.0000           | 80                  | 1.0500                                        | 0.2680                           | 5.1657          | 1.3844                      | 0.0000 |

|      |   |        |    |        |        |        |        |        |
|------|---|--------|----|--------|--------|--------|--------|--------|
| 23.5 | 0 | 0.0000 | 80 | 1.0000 | 0.2160 | 5.0990 | 1.1014 | 0.0000 |
| 24.0 | 0 | 0.0000 | 78 | 0.9200 | 0.2150 | 4.9924 | 1.0734 | 0.0000 |

Subject 2, Task 1, PWC calculation

| Work Load | HR    | VO2    |
|-----------|-------|--------|
|           | X     | Y      |
| 1         | 98.75 | 0.9515 |
| 2         | 113.5 | 1.323  |
| 3         | 133   | 1.95   |

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | -1.96495 |
| Std Err of Y Est    | 0.047622 |
| R Squared           | 0.995548 |
| No. of Observations | 3        |
| Degrees of Freedom  | 1        |

|                  |            |
|------------------|------------|
| X Coefficient(s) | 0.02931023 |
| Std Err of Coef. | 0.00196006 |

Max. HR            194

PWC            3.7212322



Subject 2, Test 1

| Equation Type      | Equation                                            | Equation Parameters                      |
|--------------------|-----------------------------------------------------|------------------------------------------|
| regression<br>i/t  | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | $D = 0.42 \quad \alpha = 0.61$           |
| balance            | $X1 + X2 = X3 + X4$                                 |                                          |
| regression<br>gain | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | $D = 0.79 \quad \alpha = 0.10$           |
| i/t                | $X4 = \text{Coef} \cdot X5 + C$                     | $\text{Coef} = 0.0316 \quad C = -2.0825$ |
| balance            | $X4 + X6 = X7 + X8$                                 |                                          |
| gain               | $X9 = Y \cdot X8$                                   | $Y = 4.9573$                             |
| balance            | $X9 = X10 + X11 + X12$                              |                                          |
| exogenous          |                                                     |                                          |
| regression         | $X10 = \text{Eff} \cdot X11$                        | $\text{Eff} = 0.3126$                    |
| exogenous          | $X12 = \text{RM}$                                   | $\text{RM} = 1.1359$                     |

|   |        |        |    |       |        |        |       |    |    |       |   |   |     |   |        |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|---|-----|---|--------|-----|
| 1 | 1.4524 | 0.9286 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0      |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.058 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0      |     |
| 0 | 0      | 0      | 1  | 0     | 0.1266 | 1.1392 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0      |     |
| 0 | 0      | 0      | -1 | 0.032 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 2.0825 |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.24  | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.957 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0      | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.313 | 0 | 0 | X11 | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | 1 | X12 | = | 1.1359 |     |

Subject 2, Task 1, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.20 | -0.06 | -0.12 | 0.26 | 74.26  | -0.24 | -0.21 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 1.00  | 0.27 | -0.12 | -0.10 | 0.24 | 73.60  | -0.21 | -0.19 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 2.00  | 0.23 | -0.10 | -0.10 | 0.23 | 73.34  | -0.19 | -0.19 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 3.00  | 0.23 | -0.10 | -0.10 | 0.23 | 73.23  | -0.19 | -0.18 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 4.00  | 0.23 | -0.10 | -0.10 | 0.23 | 73.18  | -0.18 | -0.18 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 5.00  | 0.23 | -0.10 | -0.10 | 0.23 | 73.17  | -0.18 | -0.18 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 6.00  | 0.42 | -0.10 | -0.30 | 0.62 | 85.43  | -0.18 | -0.52 | 0.96 | 4.75 | 0.86 | 2.75 | 1.14 |
| 7.00  | 0.76 | -0.30 | -0.35 | 0.82 | 91.80  | -0.52 | -0.66 | 0.96 | 4.75 | 0.86 | 2.75 | 1.14 |
| 8.00  | 0.87 | -0.35 | -0.38 | 0.90 | 94.40  | -0.66 | -0.72 | 0.96 | 4.75 | 0.86 | 2.75 | 1.14 |
| 9.00  | 0.92 | -0.38 | -0.39 | 0.93 | 95.47  | -0.72 | -0.74 | 0.96 | 4.75 | 0.86 | 2.75 | 1.14 |
| 10.00 | 1.04 | -0.39 | -0.50 | 1.14 | 102.04 | -0.74 | -0.92 | 1.32 | 6.55 | 1.29 | 4.13 | 1.14 |
| 11.00 | 1.22 | -0.50 | -0.53 | 1.25 | 105.40 | -0.92 | -0.99 | 1.32 | 6.55 | 1.29 | 4.13 | 1.14 |
| 12.00 | 1.28 | -0.53 | -0.55 | 1.29 | 106.78 | -0.99 | -1.02 | 1.32 | 6.55 | 1.29 | 4.13 | 1.14 |
| 13.00 | 1.30 | -0.55 | -0.55 | 1.31 | 107.34 | -1.02 | -1.04 | 1.32 | 6.55 | 1.29 | 4.13 | 1.14 |
| 14.00 | 1.31 | -0.55 | -0.55 | 1.32 | 107.57 | -1.04 | -1.04 | 1.32 | 6.55 | 1.29 | 4.13 | 1.14 |
| 15.00 | 1.47 | -0.55 | -0.72 | 1.64 | 117.89 | -1.04 | -1.33 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 16.00 | 1.76 | -0.72 | -0.77 | 1.81 | 123.24 | -1.33 | -1.44 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 17.00 | 1.86 | -0.77 | -0.79 | 1.88 | 125.42 | -1.44 | -1.49 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 18.00 | 1.90 | -0.79 | -0.80 | 1.91 | 126.31 | -1.49 | -1.51 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 19.00 | 1.92 | -0.80 | -0.81 | 1.92 | 126.68 | -1.51 | -1.52 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 20.00 | 1.92 | -0.81 | -0.81 | 1.93 | 126.83 | -1.52 | -1.52 | 1.93 | 9.56 | 2.01 | 6.42 | 1.14 |
| 21.00 | 1.71 | -0.81 | -0.57 | 1.47 | 112.57 | -1.52 | -1.13 | 1.08 | 5.35 | 1.00 | 3.21 | 1.14 |
| 22.00 | 1.09 | -0.57 | -0.27 | 0.79 | 90.84  | -1.13 | -0.57 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 23.00 | 0.56 | -0.27 | -0.17 | 0.46 | 80.37  | -0.57 | -0.34 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |
| 24.00 | 0.37 | -0.17 | -0.13 | 0.32 | 76.10  | -0.34 | -0.25 | 0.23 | 1.14 | 0.00 | 0.00 | 1.14 |



Subject 3, Task 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|---------|
| 0.5                  | 0                     | 0.0000           | 88                  | 0.6800                                        | 0.5690                           | 4.6724          | 2.6586                      | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 86                  | 0.7000                                        | 0.5310                           | 4.6991          | 2.4952                      | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 81                  | 0.7000                                        | 0.4280                           | 4.6991          | 2.0112                      | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 84                  | 0.7200                                        | 0.9130                           | 4.7258          | 4.3146                      | 0.0000  |
| 2.5                  | 60                    | 0.8598           | 97                  | 0.7100                                        | 0.5910                           | 4.7124          | 2.7850                      | -0.6873 |
| 3.0                  | 60                    | 0.8598           | 103                 | 0.6800                                        | 0.7990                           | 4.6724          | 3.7333                      | -2.8406 |
| 3.5                  | 60                    | 0.8598           | 113                 | 0.6800                                        | 1.2650                           | 4.6724          | 5.9106                      | 0.4586  |
| 4.0                  | 60                    | 0.8598           | 107                 | 0.7300                                        | 1.2570                           | 4.7391          | 5.9570                      | 0.4476  |
| 4.5                  | 60                    | 0.8598           | 111                 | 0.7400                                        | 1.3040                           | 4.7524          | 6.1972                      | 0.3978  |
| 5.0                  | 60                    | 0.8598           | 108                 | 0.7700                                        | 1.4270                           | 4.7924          | 6.8388                      | 0.3068  |
| 5.5                  | 60                    | 0.8598           | 107                 | 0.7900                                        | 1.2720                           | 4.8191          | 6.1299                      | 0.4106  |
| 6.0                  | 60                    | 0.8598           | 110                 | 0.8000                                        | 1.4200                           | 4.8324          | 6.8620                      | 0.3042  |
| 6.5                  | 120                   | 1.7196           | 122                 | 0.8400                                        | 1.4690                           | 4.8857          | 7.1771                      | 0.7538  |
| 7.0                  | 120                   | 1.7196           | 126                 | 0.8600                                        | 1.6320                           | 4.9124          | 8.0170                      | 0.5509  |
| 7.5                  | 120                   | 1.7196           | 134                 | 0.8600                                        | 1.9900                           | 4.9124          | 9.7756                      | 0.3524  |
| 8.0                  | 120                   | 1.7196           | 131                 | 0.9000                                        | 1.9370                           | 4.9657          | 9.6186                      | 0.3641  |
| 8.5                  | 120                   | 1.7196           | 130                 | 0.9000                                        | 2.0240                           | 4.9657          | 10.0506                     | 0.3336  |
| 9.0                  | 120                   | 1.7196           | 131                 | 0.8800                                        | 2.0840                           | 4.9390          | 10.2930                     | 0.3186  |
| 9.5                  | 120                   | 1.7196           | 132                 | 0.8900                                        | 2.0790                           | 4.9524          | 10.2960                     | 0.3184  |
| 10.0                 | 120                   | 1.7196           | 135                 | 0.8900                                        | 2.1010                           | 4.9524          | 10.4049                     | 0.3121  |
| 10.5                 | 150                   | 2.1495           | 140                 | 0.9000                                        | 2.2490                           | 4.9657          | 11.1679                     | 0.3679  |
| 11.0                 | 150                   | 2.1495           | 144                 | 0.9000                                        | 2.3590                           | 4.9657          | 11.7141                     | 0.3365  |
| 11.5                 | 150                   | 2.1495           | 152                 | 0.9300                                        | 2.6020                           | 5.0057          | 13.0248                     | 0.2792  |
| 12.0                 | 150                   | 2.1495           | 152                 | 0.9600                                        | 2.7020                           | 5.0457          | 13.6334                     | 0.2587  |
| 12.5                 | 150                   | 2.1495           | 155                 | 0.9800                                        | 2.7800                           | 5.0723          | 14.1011                     | 0.2449  |
| 13.0                 | 150                   | 2.1495           | 154                 | 0.9600                                        | 2.7370                           | 5.0457          | 13.8100                     | 0.2533  |
| 13.5                 | 150                   | 2.1495           | 155                 | 0.9600                                        | 2.7750                           | 5.0457          | 14.0018                     | 0.2477  |
| 14.0                 | 150                   | 2.1495           | 158                 | 0.9500                                        | 2.8020                           | 5.0324          | 14.1006                     | 0.2450  |
| 14.5                 | 0                     | 0.0000           | 134                 | 0.9600                                        | 2.5570                           | 5.0457          | 12.9018                     | 0.0000  |
| 15.0                 | 0                     | 0.0000           | 116                 | 1.1200                                        | 1.4020                           | 5.2590          | 7.3731                      | 0.0000  |
| 15.5                 | 0                     | 0.0000           | 103                 | 1.1800                                        | 0.8970                           | 5.3389          | 4.7890                      | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 99                  | 1.1600                                        | 0.7740                           | 5.3123          | 4.1117                      | 0.0000  |
| 16.5                 | 0                     | 0.0000           | 92                  | 1.1100                                        | 0.7000                           | 5.2456          | 3.6719                      | 0.0000  |
| 17.0                 | 0                     | 0.0000           | 94                  | 1.0800                                        | 0.6850                           | 5.2056          | 3.5659                      | 0.0000  |
| 17.5                 | 0                     | 0.0000           | 102                 | 1.0300                                        | 0.8180                           | 5.1390          | 4.2037                      | 0.0000  |
| 18.0                 | 0                     | 0.0000           | 92                  | 1.0400                                        | 0.5290                           | 5.1523          | 2.7256                      | 0.0000  |
| 18.5                 | 0                     | 0.0000           | 95                  | 0.9800                                        | 0.6420                           | 5.0723          | 3.2564                      | 0.0000  |
| 19.0                 | 0                     | 0.0000           | 96                  | 0.9600                                        | 0.7420                           | 5.0457          | 3.7439                      | 0.0000  |

Subject 3, Task 1, PWC calculation

| Work Load | HR    | VO2   |
|-----------|-------|-------|
|           | X     | Y     |
| 1         | 109   | 1.356 |
| 2         | 132   | 2.072 |
| 3         | 155.5 | 2.774 |

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | -1.96274 |
| Std Err of Y Est    | 0.01194  |
| R Squared           | 0.999858 |
| No. of Observations | 3        |
| Degrees of Freedom  | 1        |

|                  |            |
|------------------|------------|
| X Coefficient(s) | 0.03049237 |
| Std Err of Coef. | 0.00036312 |

Max. HR            191

PWC                3.861301

Subject 3, Test 1

stop

| Equation Type     | Equation                                            | Equation Parameters |        |       |         |
|-------------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression<br>i/t | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.42   | alfa= | 0.61    |
| balance           | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| regression        | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.79   | alfa= | 0.10    |
| gain<br>i/t       | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0316 | C =   | -2.0825 |
| balance           | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| gain              | $X9 = Y \cdot X8$                                   | Y =                 | 4.9573 |       |         |
| balance           | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| exogenous         |                                                     |                     |        |       |         |
| regression        | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.3126 |       |         |
| exogenous         | $X12 = \text{RM}$                                   | RM =                | 3.1762 |       |         |

|    |        |        |    |       |        |        |       |    |    |       |   |     |   |         |     |
|----|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|-----|---|---------|-----|
| -1 | 1.4524 | 0.9286 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X1  | = | 0       |     |
| 0  | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.059  | i/t |
| 1  | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X3  | = | 0       |     |
| 0  | 0      | 0      | 1  | 0     | 0.1266 | 1.1392 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0       |     |
| 0  | 0      | 0      | -1 | 0.032 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X5  | = | 2.0825  |     |
| 0  | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.6    | i/t |
| 0  | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | X7  | = | 0       |     |
| 0  | 0      | 0      | 0  | 0     | 0      | 0      | 4.957 | -1 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0  | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0  | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0  | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.313 | 0 | X11 | = | 0       |     |
| 0  | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | X12 | = | 3.17616 |     |

Subject 3, Task 1, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9    | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|-------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.41 | -0.06 | -0.35 | 0.70 | 87.93  | -0.60 | -0.54 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 1.00  | 0.75 | -0.35 | -0.26 | 0.66 | 86.89  | -0.54 | -0.52 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 2.00  | 0.64 | -0.26 | -0.28 | 0.65 | 86.47  | -0.52 | -0.51 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 3.00  | 0.84 | -0.28 | -0.47 | 1.03 | 98.57  | -0.51 | -0.85 | 1.37 | 6.79  | 0.86 | 2.75 | 3.18 |
| 4.00  | 1.17 | -0.47 | -0.53 | 1.23 | 104.87 | -0.85 | -0.99 | 1.37 | 6.79  | 0.86 | 2.75 | 3.18 |
| 5.00  | 1.28 | -0.53 | -0.56 | 1.31 | 107.45 | -0.99 | -1.04 | 1.37 | 6.79  | 0.86 | 2.75 | 3.18 |
| 6.00  | 1.34 | -0.56 | -0.57 | 1.35 | 108.50 | -1.04 | -1.07 | 1.37 | 6.79  | 0.86 | 2.75 | 3.18 |
| 7.00  | 1.54 | -0.57 | -0.77 | 1.75 | 121.20 | -1.07 | -1.42 | 2.10 | 10.40 | 1.72 | 5.50 | 3.18 |
| 8.00  | 1.90 | -0.77 | -0.83 | 1.95 | 127.75 | -1.42 | -1.56 | 2.10 | 10.40 | 1.72 | 5.50 | 3.18 |
| 9.00  | 2.01 | -0.83 | -0.86 | 2.04 | 130.43 | -1.56 | -1.62 | 2.10 | 10.40 | 1.72 | 5.50 | 3.18 |
| 10.00 | 2.06 | -0.86 | -0.87 | 2.07 | 131.52 | -1.62 | -1.64 | 2.10 | 10.40 | 1.72 | 5.50 | 3.18 |
| 11.00 | 2.18 | -0.87 | -0.98 | 2.28 | 138.10 | -1.64 | -1.82 | 2.46 | 12.20 | 2.15 | 6.88 | 3.18 |
| 12.00 | 2.36 | -0.98 | -1.01 | 2.39 | 141.47 | -1.82 | -1.89 | 2.46 | 12.20 | 2.15 | 6.88 | 3.18 |
| 13.00 | 2.42 | -1.01 | -1.02 | 2.43 | 142.84 | -1.89 | -1.92 | 2.46 | 12.20 | 2.15 | 6.88 | 3.18 |
| 14.00 | 2.44 | -1.02 | -1.03 | 2.45 | 143.41 | -1.92 | -1.94 | 2.46 | 12.20 | 2.15 | 6.88 | 3.18 |
| 15.00 | 1.99 | -1.03 | -0.53 | 1.49 | 112.95 | -1.94 | -1.09 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 16.00 | 1.13 | -0.53 | -0.39 | 0.99 | 97.11  | -1.09 | -0.74 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 17.00 | 0.85 | -0.39 | -0.31 | 0.78 | 90.64  | -0.74 | -0.60 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 18.00 | 0.72 | -0.31 | -0.29 | 0.70 | 88.00  | -0.60 | -0.55 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |
| 19.00 | 0.68 | -0.29 | -0.28 | 0.66 | 86.92  | -0.55 | -0.52 | 0.64 | 3.18  | 0.00 | 0.00 | 3.18 |

Subject 4, Task 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|---------|
| 0.5                  | 0                     | 0.0000           | 95                  | 0.7600               | 1.0280               | 4.7791          | 4.9129          | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 95                  | 0.8100               | 0.9530               | 4.8457          | 4.6180          | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 96                  | 0.8300               | 0.9010               | 4.8724          | 4.3900          | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 93                  | 0.8400               | 0.8370               | 4.8857          | 4.0893          | 0.0000  |
| 2.5                  | 0                     | 0.0000           | 94                  | 0.8400               | 0.7510               | 4.8857          | 3.6692          | 0.0000  |
| 3.0                  | 0                     | 0.0000           | 94                  | 0.8400               | 0.8640               | 4.8857          | 4.2213          | 0.0000  |
| 3.5                  | 50                    | 0.7165           | 102                 | 0.8400               | 0.8670               | 4.8857          | 4.2359          | -0.6096 |
| 4.0                  | 50                    | 0.7165           | 111                 | 0.8100               | 1.1710               | 4.8457          | 5.6743          | 2.7238  |
| 4.5                  | 50                    | 0.7165           | 112                 | 0.7900               | 1.6490               | 4.8191          | 7.9466          | 0.2826  |
| 5.0                  | 50                    | 0.7165           | 114                 | 0.8100               | 1.5910               | 4.8457          | 7.7096          | 0.3118  |
| 5.5                  | 50                    | 0.7165           | 111                 | 0.8500               | 1.6670               | 4.8991          | 8.1667          | 0.2600  |
| 6.0                  | 50                    | 0.7165           | 112                 | 0.8400               | 1.6470               | 4.8857          | 8.0468          | 0.2719  |
| 6.5                  | 50                    | 0.7165           | 115                 | 0.8500               | 1.6340               | 4.8991          | 8.0050          | 0.2762  |
| 7.0                  | 50                    | 0.7165           | 115                 | 0.8500               | 1.7050               | 4.8991          | 8.3529          | 0.2436  |
| 7.5                  | 100                   | 1.4330           | 122                 | 0.8600               | 1.7050               | 4.9124          | 8.3756          | 0.6375  |
| 8.0                  | 100                   | 1.4330           | 126                 | 0.8800               | 1.9890               | 4.9390          | 9.8238          | 0.3877  |
| 8.5                  | 100                   | 1.4330           | 130                 | 0.9100               | 2.1470               | 4.9790          | 10.6900         | 0.3141  |
| 9.0                  | 100                   | 1.4330           | 134                 | 0.9400               | 2.2700               | 5.0190          | 11.3932         | 0.2722  |
| 9.5                  | 100                   | 1.4330           | 131                 | 0.9400               | 2.2350               | 5.0190          | 11.2175         | 0.2815  |
| 10.0                 | 100                   | 1.4330           | 134                 | 0.9500               | 2.2260               | 5.0324          | 11.2020         | 0.2824  |
| 10.5                 | 100                   | 1.4330           | 133                 | 0.9300               | 2.1920               | 5.0057          | 10.9725         | 0.2958  |
| 11.0                 | 100                   | 1.4330           | 135                 | 0.9500               | 2.3060               | 5.0324          | 11.6046         | 0.2616  |
| 11.5                 | 140                   | 2.0062           | 145                 | 0.9300               | 2.3560               | 5.0057          | 11.7934         | 0.3940  |
| 12.0                 | 140                   | 2.0062           | 146                 | 0.9500               | 2.6080               | 5.0324          | 13.1244         | 0.3123  |
| 12.5                 | 140                   | 2.0062           | 149                 | 0.9800               | 2.7910               | 5.0723          | 14.1569         | 0.2691  |
| 13.0                 | 140                   | 2.0062           | 151                 | 0.9900               | 2.8600               | 5.0857          | 14.5450         | 0.2558  |
| 13.5                 | 140                   | 2.0062           | 153                 | 1.0000               | 3.0180               | 5.0990          | 15.3888         | 0.2309  |
| 14.0                 | 140                   | 2.0062           | 152                 | 1.0200               | 3.0800               | 5.1257          | 15.7870         | 0.2208  |
| 14.5                 | 140                   | 2.0062           | 152                 | 1.0000               | 3.0710               | 5.0990          | 15.6590         | 0.2240  |
| 15.0                 | 140                   | 2.0062           | 152                 | 0.9600               | 2.9350               | 5.0457          | 14.8091         | 0.2474  |
| 15.5                 | 140                   | 2.0062           | 155                 | 0.9400               | 3.0030               | 5.0190          | 15.0721         | 0.2397  |
| 16.0                 | 140                   | 2.0062           | 154                 | 0.9500               | 3.1300               | 5.0324          | 15.7513         | 0.2217  |
| 16.5                 | 0                     | 0.0000           | 138                 | 0.9400               | 2.8100               | 5.0190          | 14.1034         | 0.0000  |
| 17.0                 | 0                     | 0.0000           | 127                 | 1.0600               | 2.0480               | 5.1790          | 10.6066         | 0.0000  |
| 17.5                 | 0                     | 0.0000           | 124                 | 1.2100               | 1.4130               | 5.3789          | 7.6004          | 0.0000  |
| 18.0                 | 0                     | 0.0000           | 121                 | 1.1600               | 1.2020               | 5.3123          | 6.3854          | 0.0000  |
| 18.5                 | 0                     | 0.0000           | 123                 | 1.1000               | 1.0780               | 5.2323          | 5.6404          | 0.0000  |
| 19.0                 | 0                     | 0.0000           | 125                 | 1.0500               | 1.0760               | 5.1657          | 5.5582          | 0.0000  |
| 19.5                 | 0                     | 0.0000           | 118                 | 0.9700               | 0.9550               | 5.0590          | 4.8314          | 0.0000  |
| 20.0                 | 0                     | 0.0000           | 120                 | 0.9800               | 1.0170               | 5.0723          | 5.1586          | 0.0000  |



Subject 4, Task 1, PWC calculation

| Work Load | HR<br>X | VO2<br>Y |
|-----------|---------|----------|
| 1         | 113.25  | 1.663    |
| 2         | 133.25  | 2.24     |
| 3         | 153.25  | 3.035    |

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | -2.25781 |
| Std Err of Y Est    | 0.088998 |
| R Squared           | 0.991655 |
| No. of Observations | 3        |
| Degrees of Freedom  | 1        |

|                  |            |
|------------------|------------|
| X Coefficient(s) | 0.0343     |
| Std Err of Coef. | 0.00314656 |

Max. HR      193

PWC      4.362092

## Subject 4, Test 1

|               |                                                     |                     |        |                 |
|---------------|-----------------------------------------------------|---------------------|--------|-----------------|
| Equation Type | Equation                                            | Equation Parameters |        |                 |
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.42   | $\alpha =$ 0.61 |
| i/t           |                                                     |                     |        |                 |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |                 |
| regression    | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.79   | $\alpha =$ 0.10 |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0316 | C = -2.0825     |
| i/t           |                                                     |                     |        |                 |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |                 |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 4.9573 |                 |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |                 |
| exogenous     |                                                     |                     |        |                 |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.3126 |                 |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 4.6948 |                 |

|   |        |        |    |       |        |        |       |    |    |       |   |     |   |        |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|-----|---|--------|-----|
| 1 | 1.4524 | 0.9286 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X1  | = | 0      |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.44  | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X3  | = | 0      |     |
| 0 | 0      | 0      | 1  | 0     | 0.1266 | 1.1392 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0      |     |
| 0 | 0      | 0      | -1 | 0.032 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X5  | = | 2.0825 |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.51  | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | X7  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.957 | -1 | 0  | 0     | 0 | X8  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | X9  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | X10 | = | 0      | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.313 | 0 | X11 | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | X12 | = | 4.6948 |     |

Subject 4, Task 1, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9    | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|-------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.93 | -0.44 | -0.31 | 0.81 | 91.41  | -0.51 | -0.65 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 1.00  | 0.82 | -0.31 | -0.39 | 0.89 | 94.05  | -0.65 | -0.71 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 2.00  | 0.92 | -0.39 | -0.39 | 0.92 | 95.13  | -0.71 | -0.73 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 3.00  | 0.93 | -0.39 | -0.40 | 0.94 | 95.57  | -0.73 | -0.74 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 4.00  | 1.10 | -0.40 | -0.56 | 1.27 | 105.98 | -0.74 | -1.03 | 1.55 | 7.70  | 0.72 | 2.29 | 4.69 |
| 5.00  | 1.39 | -0.56 | -0.61 | 1.44 | 111.36 | -1.03 | -1.15 | 1.55 | 7.70  | 0.72 | 2.29 | 4.69 |
| 6.00  | 1.48 | -0.61 | -0.64 | 1.51 | 113.56 | -1.15 | -1.19 | 1.55 | 7.70  | 0.72 | 2.29 | 4.69 |
| 7.00  | 1.53 | -0.64 | -0.65 | 1.53 | 114.46 | -1.19 | -1.21 | 1.55 | 7.70  | 0.72 | 2.29 | 4.69 |
| 8.00  | 1.70 | -0.65 | -0.82 | 1.87 | 125.05 | -1.21 | -1.51 | 2.16 | 10.71 | 1.43 | 4.58 | 4.69 |
| 9.00  | 1.99 | -0.82 | -0.87 | 2.04 | 130.51 | -1.51 | -1.62 | 2.16 | 10.71 | 1.43 | 4.58 | 4.69 |
| 10.00 | 2.09 | -0.87 | -0.89 | 2.11 | 132.74 | -1.62 | -1.67 | 2.16 | 10.71 | 1.43 | 4.58 | 4.69 |
| 11.00 | 2.13 | -0.89 | -0.90 | 2.14 | 133.65 | -1.67 | -1.69 | 2.16 | 10.71 | 1.43 | 4.58 | 4.69 |
| 12.00 | 2.27 | -0.90 | -1.04 | 2.41 | 142.21 | -1.69 | -1.93 | 2.65 | 13.12 | 2.01 | 6.42 | 4.69 |
| 13.00 | 2.51 | -1.04 | -1.08 | 2.55 | 146.61 | -1.93 | -2.02 | 2.65 | 13.12 | 2.01 | 6.42 | 4.69 |
| 14.00 | 2.59 | -1.08 | -1.10 | 2.61 | 148.41 | -2.02 | -2.06 | 2.65 | 13.12 | 2.01 | 6.42 | 4.69 |
| 15.00 | 2.62 | -1.10 | -1.11 | 2.63 | 149.14 | -2.06 | -2.08 | 2.65 | 13.12 | 2.01 | 6.42 | 4.69 |
| 16.00 | 2.64 | -1.11 | -1.11 | 2.64 | 149.44 | -2.08 | -2.09 | 2.65 | 13.12 | 2.01 | 6.42 | 4.69 |
| 17.00 | 2.21 | -1.11 | -0.64 | 1.74 | 120.93 | -2.09 | -1.29 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 18.00 | 1.40 | -0.64 | -0.51 | 1.27 | 106.10 | -1.29 | -0.97 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 19.00 | 1.15 | -0.51 | -0.44 | 1.08 | 100.05 | -0.97 | -0.84 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |
| 20.00 | 1.03 | -0.44 | -0.42 | 1.00 | 97.58  | -0.84 | -0.79 | 0.95 | 4.69  | 0.00 | 0.00 | 4.69 |



Subject 5, Task 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 100                 | 0.9000               | 0.2120               | 4.9657          | 1.0527          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 106                 | 0.8900               | 0.1300               | 4.9524          | 0.6438          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 90                  | 0.8400               | 0.1310               | 4.8857          | 0.6400          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 98                  | 0.8300               | 0.0770               | 4.8724          | 0.3752          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 93                  | 0.8400               | 0.1530               | 4.8857          | 0.7475          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 90                  | 0.8400               | 0.1260               | 4.8857          | 0.6156          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 101                 | 0.8300               | 0.1170               | 4.8724          | 0.5701          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 107                 | 0.8000               | 0.1090               | 4.8324          | 0.5267          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 87                  | 0.7800               | 0.0920               | 4.8057          | 0.4421          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 99                  | 0.8400               | 0.1640               | 4.8857          | 0.8013          | 0.0000 |
| 5.5                  | 50                    | 0.7165           | 122                 | 0.8300               | 0.4020               | 4.8724          | 1.9587          | 1.3132 |
| 6.0                  | 50                    | 0.7165           | 120                 | 0.7600               | 0.7180               | 4.7791          | 3.4314          | 0.3550 |
| 6.5                  | 50                    | 0.7165           | 117                 | 0.7500               | 0.6970               | 4.7658          | 3.3217          | 0.3754 |
| 7.0                  | 50                    | 0.7165           | 117                 | 0.7600               | 0.6990               | 4.7791          | 3.3406          | 0.3717 |
| 7.5                  | 50                    | 0.7165           | 119                 | 0.7600               | 0.6650               | 4.7791          | 3.1781          | 0.4059 |
| 8.0                  | 50                    | 0.7165           | 113                 | 0.7700               | 0.7250               | 4.7924          | 3.4745          | 0.3476 |
| 8.5                  | 50                    | 0.7165           | 114                 | 0.7800               | 0.7420               | 4.8057          | 3.5659          | 0.3328 |
| 9.0                  | 50                    | 0.7165           | 114                 | 0.8000               | 0.7640               | 4.8324          | 3.6920          | 0.3144 |
| 9.5                  | 50                    | 0.7165           | 112                 | 0.8000               | 0.7520               | 4.8324          | 3.6340          | 0.3226 |
| 10.0                 | 50                    | 0.7165           | 117                 | 0.8200               | 0.7440               | 4.8591          | 3.6151          | 0.3254 |
| 10.5                 | 50                    | 0.7165           | 117                 | 0.8400               | 0.8050               | 4.8857          | 3.9330          | 0.2843 |
| 11.0                 | 50                    | 0.7165           | 109                 | 0.8700               | 0.7940               | 4.9257          | 3.9110          | 0.2868 |
| 11.5                 | 100                   | 1.4330           | 125                 | 0.8400               | 0.8040               | 4.8857          | 3.9281          | 0.7968 |
| 12.0                 | 100                   | 1.4330           | 130                 | 0.8100               | 1.0560               | 4.8457          | 5.1171          | 0.4797 |
| 12.5                 | 100                   | 1.4330           | 128                 | 0.8200               | 1.2480               | 4.8591          | 6.0641          | 0.3642 |
| 13.0                 | 100                   | 1.4330           | 123                 | 0.8300               | 1.2290               | 4.8724          | 5.9882          | 0.3714 |
| 13.5                 | 100                   | 1.4330           | 125                 | 0.8400               | 1.2560               | 4.8857          | 6.1365          | 0.3576 |
| 14.0                 | 100                   | 1.4330           | 131                 | 0.8500               | 1.2960               | 4.8991          | 6.3492          | 0.3396 |
| 14.5                 | 100                   | 1.4330           | 129                 | 0.8700               | 1.2810               | 4.9257          | 6.3098          | 0.3428 |
| 15.0                 | 100                   | 1.4330           | 127                 | 0.8800               | 1.2940               | 4.9390          | 6.3911          | 0.3363 |
| 15.5                 | 100                   | 1.4330           | 130                 | 0.8700               | 1.2940               | 4.9257          | 6.3739          | 0.3376 |
| 16.0                 | 100                   | 1.4330           | 131                 | 0.8600               | 1.2050               | 4.9124          | 5.9194          | 0.3781 |
| 16.5                 | 150                   | 2.1495           | 139                 | 0.8700               | 1.3730               | 4.9257          | 6.7630          | 0.5488 |
| 17.0                 | 150                   | 2.1495           | 146                 | 0.8700               | 1.6680               | 4.9257          | 8.2161          | 0.4003 |
| 17.5                 | 150                   | 2.1495           | 147                 | 0.8900               | 1.8250               | 4.9524          | 9.0381          | 0.3471 |
| 18.0                 | 150                   | 2.1495           | 148                 | 0.9100               | 1.8990               | 4.9790          | 9.4552          | 0.3252 |
| 18.5                 | 150                   | 2.1495           | 148                 | 0.9100               | 1.8640               | 4.9790          | 9.2809          | 0.3340 |
| 19.0                 | 150                   | 2.1495           | 151                 | 0.9100               | 1.8860               | 4.9790          | 9.3905          | 0.3285 |
| 19.5                 | 150                   | 2.1495           | 151                 | 0.9000               | 1.8000               | 4.9657          | 8.9383          | 0.3528 |
| 20.0                 | 150                   | 2.1495           | 150                 | 0.8800               | 1.8130               | 4.9390          | 8.9545          | 0.3519 |
| 20.5                 | 150                   | 2.1495           | 152                 | 0.8900               | 1.9180               | 4.9524          | 9.4986          | 0.3231 |
| 21.0                 | 150                   | 2.1495           | 151                 | 0.9000               | 1.8670               | 4.9657          | 9.2710          | 0.3346 |
| 21.5                 | 0                     | 0.0000           | 129                 | 0.9300               | 1.4380               | 5.0057          | 7.1982          | 0.0000 |
| 22.0                 | 0                     | 0.0000           | 117                 | 1.0400               | 0.8050               | 5.1523          | 4.1476          | 0.0000 |
| 22.5                 | 0                     | 0.0000           | 106                 | 1.1400               | 0.3790               | 5.2856          | 2.0032          | 0.0000 |
| 23.0                 | 0                     | 0.0000           | 110                 | 1.0800               | 0.2530               | 5.2056          | 1.3170          | 0.0000 |

|      |   |        |     |        |        |        |        |        |
|------|---|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 0 | 0.0000 | 111 | 1.0400 | 0.2580 | 5.1523 | 1.3293 | 0.0000 |
| 24.0 | 0 | 0.0000 | 101 | 1.0300 | 0.2260 | 5.1390 | 1.1614 | 0.0000 |
| 24.5 | 0 | 0.0000 | 105 | 1.0000 | 0.1880 | 5.0990 | 0.9586 | 0.0000 |
| 25.0 | 0 | 0.0000 | 103 | 0.9800 | 0.2240 | 5.0723 | 1.1362 | 0.0000 |
| 25.5 | 0 | 0.0000 | 104 | 0.9500 | 0.1530 | 5.0324 | 0.7699 | 0.0000 |
| 26.0 | 0 | 0.0000 | 98  | 0.9500 | 0.1780 | 5.0324 | 0.8958 | 0.0000 |
| 26.5 | 0 | 0.0000 | 95  | 0.9700 | 0.1870 | 5.0590 | 0.9460 | 0.0000 |
| 27.0 | 0 | 0.0000 | 111 | 0.9000 | 0.1250 | 4.9657 | 0.6207 | 0.0000 |

Subject 5, Task 1, PWC calculation

| Work Load | HR<br>X | VO2<br>Y |
|-----------|---------|----------|
| 1         | 113.75  | 0.7738   |
| 2         | 129.25  | 1.2685   |
| 3         | 151     | 1.8495   |

Regression Output:

|                     |          |
|---------------------|----------|
| Constant            | -2.47696 |
| Std Err of Y Est    | 0.038272 |
| R Squared           | 0.997474 |
| No. of Observations | 3        |
| Degrees of Freedom  | 1        |

|                  |            |
|------------------|------------|
| X Coefficient(s) | 0.02873775 |
| Std Err of Coef. | 0.00144626 |

Max. HR      194

PWC      3.098166

Subject 5, Test 1

stop

| Equation Type     | Equation                                | Equation Parameters |        |       |         |
|-------------------|-----------------------------------------|---------------------|--------|-------|---------|
| regression<br>i/t | $X1 = -1/D (\alpha X2 + (1-\alpha) X3)$ | D=                  | 0.42   | alfa= | 0.61    |
| balance           | $X1 + X2 = X3 + X4$                     |                     |        |       |         |
| regression        | $X4 = -1/D (\alpha X6 + (1-\alpha) X7)$ | D=                  | 0.79   | alfa= | 0.10    |
| gain<br>i/t       | $X4 = \text{Coef} * X5 + C$             | Coef =              | 0.0316 | C =   | -2.0825 |
| balance           | $X4 + X6 = X7 + X8$                     |                     |        |       |         |
| gain              | $X9 = Y * X8$                           | Y =                 | 4.9573 |       |         |
| balance           | $X9 = X10 + X11 + X12$                  |                     |        |       |         |
| exogenous         |                                         |                     |        |       |         |
| regression        | $X10 = \text{Eff} * X11$                | Eff =               | 0.3126 |       |         |
| exogenous         | $X12 = \text{RM}$                       | RM =                | 0.6966 |       |         |

|   |        |        |    |       |        |        |       |    |    |       |   |     |   |        |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|-----|---|--------|-----|
| 1 | 1.4524 | 0.9286 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X1  | = | 0      |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.067 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X3  | = | 0      |     |
| 0 | 0      | 0      | 1  | 0     | 0.1266 | 1.1392 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0      |     |
| 0 | 0      | 0      | -1 | 0.032 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | X5  | = | 2.0825 |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.078 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | X7  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.957 | -1 | 0  | 0     | 0 | X8  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | X9  | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | X10 | = | 0      | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.313 | 0 | X11 | = | 0      |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | X12 | = | 0.6966 |     |

Subject 5, Task 1, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.14 | -0.07 | -0.05 | 0.12 | 69.73  | -0.08 | -0.10 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 1.00  | 0.12 | -0.05 | -0.06 | 0.13 | 70.10  | -0.10 | -0.11 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 2.00  | 0.14 | -0.06 | -0.06 | 0.14 | 70.25  | -0.11 | -0.11 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 3.00  | 0.14 | -0.06 | -0.06 | 0.14 | 70.31  | -0.11 | -0.11 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 4.00  | 0.14 | -0.06 | -0.06 | 0.14 | 70.33  | -0.11 | -0.11 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 5.00  | 0.14 | -0.06 | -0.06 | 0.14 | 70.34  | -0.11 | -0.11 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 6.00  | 0.30 | -0.06 | -0.23 | 0.46 | 80.57  | -0.11 | -0.39 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 7.00  | 0.58 | -0.23 | -0.27 | 0.63 | 85.89  | -0.39 | -0.51 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 8.00  | 0.68 | -0.27 | -0.30 | 0.70 | 88.06  | -0.51 | -0.56 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 9.00  | 0.72 | -0.30 | -0.31 | 0.73 | 88.94  | -0.56 | -0.58 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 10.00 | 0.74 | -0.31 | -0.31 | 0.74 | 89.30  | -0.58 | -0.59 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 11.00 | 0.74 | -0.31 | -0.31 | 0.74 | 89.45  | -0.59 | -0.59 | 0.75 | 3.71 | 0.72 | 2.29 | 0.70 |
| 12.00 | 0.90 | -0.31 | -0.48 | 1.07 | 99.74  | -0.59 | -0.87 | 1.35 | 6.71 | 1.43 | 4.58 | 0.70 |
| 13.00 | 1.19 | -0.48 | -0.53 | 1.24 | 105.08 | -0.87 | -0.99 | 1.35 | 6.71 | 1.43 | 4.58 | 0.70 |
| 14.00 | 1.28 | -0.53 | -0.55 | 1.31 | 107.26 | -0.99 | -1.04 | 1.35 | 6.71 | 1.43 | 4.58 | 0.70 |
| 15.00 | 1.33 | -0.55 | -0.56 | 1.33 | 108.15 | -1.04 | -1.06 | 1.35 | 6.71 | 1.43 | 4.58 | 0.70 |
| 16.00 | 1.34 | -0.56 | -0.57 | 1.35 | 108.51 | -1.06 | -1.06 | 1.35 | 6.71 | 1.43 | 4.58 | 0.70 |
| 17.00 | 1.51 | -0.57 | -0.74 | 1.67 | 118.89 | -1.06 | -1.35 | 1.96 | 9.72 | 2.15 | 6.88 | 0.70 |
| 18.00 | 1.80 | -0.74 | -0.78 | 1.84 | 124.26 | -1.35 | -1.47 | 1.96 | 9.72 | 2.15 | 6.88 | 0.70 |
| 19.00 | 1.89 | -0.78 | -0.81 | 1.91 | 126.45 | -1.47 | -1.52 | 1.96 | 9.72 | 2.15 | 6.88 | 0.70 |
| 20.00 | 1.93 | -0.81 | -0.82 | 1.94 | 127.35 | -1.52 | -1.54 | 1.96 | 9.72 | 2.15 | 6.88 | 0.70 |
| 21.00 | 1.95 | -0.82 | -0.82 | 1.95 | 127.71 | -1.54 | -1.54 | 1.96 | 9.72 | 2.15 | 6.88 | 0.70 |
| 22.00 | 1.49 | -0.82 | -0.32 | 0.99 | 97.18  | -1.54 | -0.70 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 23.00 | 0.63 | -0.32 | -0.18 | 0.49 | 81.30  | -0.70 | -0.35 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 24.00 | 0.35 | -0.18 | -0.10 | 0.28 | 74.82  | -0.35 | -0.21 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 25.00 | 0.22 | -0.10 | -0.08 | 0.20 | 72.17  | -0.21 | -0.15 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 26.00 | 0.18 | -0.08 | -0.07 | 0.16 | 71.09  | -0.15 | -0.13 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |
| 27.00 | 0.15 | -0.07 | -0.06 | 0.15 | 70.65  | -0.13 | -0.12 | 0.14 | 0.70 | 0.00 | 0.00 | 0.70 |

## APPENDIX C

### Task 2 Data



Subject 1, Task 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 80                  | 0.8700               | 0.8080               | 4.9257          | 3.9800          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 81                  | 0.8900               | 0.7170               | 4.9524          | 3.5508          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 80                  | 0.8700               | 0.6290               | 4.9257          | 3.0983          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 81                  | 0.9500               | 0.7760               | 5.0324          | 3.9051          | 0.0000 |
| 2.5                  | 25                    | 0.3583           | 88                  | 0.8700               | 0.9960               | 4.9257          | 4.9060          | 0.3443 |
| 3.0                  | 25                    | 0.3583           | 94                  | 0.8800               | 0.8360               | 4.9390          | 4.1290          | 1.3601 |
| 3.5                  | 25                    | 0.3583           | 92                  | 0.9100               | 0.9910               | 4.9790          | 4.9342          | 0.3353 |
| 4.0                  | 25                    | 0.3583           | 90                  | 0.8900               | 0.9420               | 4.9524          | 4.6651          | 0.4481 |
| 4.5                  | 25                    | 0.3583           | 91                  | 0.9100               | 1.0860               | 4.9790          | 5.4072          | 0.2324 |
| 5.0                  | 25                    | 0.3583           | 89                  | 0.9000               | 0.9560               | 4.9657          | 4.7472          | 0.4064 |
| 5.5                  | 25                    | 0.3583           | 95                  | 0.8400               | 1.1340               | 4.8857          | 5.5404          | 0.2139 |
| 6.0                  | 25                    | 0.3583           | 92                  | 0.9100               | 1.1900               | 4.9790          | 5.9250          | 0.1740 |
| 6.5                  | 50                    | 0.7165           | 101                 | 0.9000               | 1.0190               | 4.9657          | 5.0600          | 0.8569 |
| 7.0                  | 50                    | 0.7165           | 101                 | 0.9200               | 1.2610               | 4.9924          | 6.2954          | 0.3459 |
| 7.5                  | 50                    | 0.7165           | 102                 | 0.9000               | 1.5070               | 4.9657          | 7.4833          | 0.2198 |
| 8.0                  | 50                    | 0.7165           | 104                 | 0.9300               | 1.4340               | 5.0057          | 7.1782          | 0.2425 |
| 8.5                  | 50                    | 0.7165           | 103                 | 0.9400               | 1.4580               | 5.0190          | 7.3177          | 0.2316 |
| 9.0                  | 50                    | 0.7165           | 105                 | 0.9300               | 1.4060               | 5.0057          | 7.0380          | 0.2546 |
| 9.5                  | 50                    | 0.7165           | 105                 | 0.9500               | 1.4910               | 5.0324          | 7.5032          | 0.2185 |
| 10.0                 | 50                    | 0.7165           | 105                 | 0.9600               | 1.4200               | 5.0457          | 7.1649          | 0.2436 |
| 10.5                 | 75                    | 1.0748           | 114                 | 0.9300               | 1.4800               | 5.0057          | 7.4084          | 0.3803 |
| 11.0                 | 75                    | 1.0748           | 114                 | 0.9400               | 1.8070               | 5.0190          | 9.0694          | 0.2395 |
| 11.5                 | 75                    | 1.0748           | 122                 | 0.9800               | 1.6680               | 5.0723          | 8.4607          | 0.2771 |
| 12.0                 | 75                    | 1.0748           | 123                 | 0.9800               | 1.7820               | 5.0723          | 9.0389          | 0.2411 |
| 12.5                 | 75                    | 1.0748           | 122                 | 0.9800               | 1.9520               | 5.0723          | 9.9012          | 0.2021 |
| 13.0                 | 75                    | 1.0748           | 121                 | 0.9700               | 1.8670               | 5.0590          | 9.4452          | 0.2210 |
| 13.5                 | 75                    | 1.0748           | 121                 | 0.9800               | 2.0290               | 5.0723          | 10.2918         | 0.1882 |
| 14.0                 | 75                    | 1.0748           | 127                 | 1.0000               | 1.8400               | 5.0990          | 9.3822          | 0.2239 |
| 14.5                 | 0                     | 0.0000           | 103                 | 0.9300               | 1.6900               | 5.0057          | 8.4596          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 83                  | 0.9700               | 1.2890               | 5.0590          | 6.5211          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 81                  | 1.0800               | 0.6820               | 5.2056          | 3.5502          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 70                  | 0.9900               | 0.5820               | 5.0857          | 2.9599          | 0.0000 |

Subject 1, Task 2, PWC calculation

| Work Load | HR     | VO2   |
|-----------|--------|-------|
| rest      |        |       |
| 1         | 91.75  | 1.092 |
| 2         | 104.5  | 1.444 |
| 3         | 122.75 | 1.922 |

Regression Output:

|                     |            |
|---------------------|------------|
| Constant            | -1.3567217 |
| Std Err of Y Est    | 0.00863339 |
| R Squared           | 0.99978526 |
| No. of Observations | 3          |
| Degrees of Freedom  | 1          |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.026734 |
| Std Err of Coef. | 0.000392 |

Max. HR            194

PWC =            3.829686



## Subject 1, Test 2

| Equation Type             | Equation                                                                               | Equation Parameters                                                        |
|---------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| regression<br>i/t         | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$                                    | $D = 0.23 \quad \alpha = 0.58$                                             |
| balance                   | $X1 + X2 = X3 + X4$                                                                    |                                                                            |
| regression<br>gain<br>i/t | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$<br>$X4 = \text{Coef} \cdot X5 + C$ | $D = 0.72 \quad \alpha = 0.32$<br>$\text{Coef} = 0.0223 \quad C = -1.1613$ |
| balance                   | $X4 + X6 = X7 + X8$                                                                    |                                                                            |
| gain                      | $X9 = Y \cdot X8$                                                                      | $Y = 5.0173$                                                               |
| balance                   | $X9 = X10 + X11 + X12$                                                                 |                                                                            |
| exogenous                 |                                                                                        |                                                                            |
| regression                | $X10 = \text{Eff} \cdot X11$                                                           | $\text{Eff} = 0.2870$                                                      |
| exogenous                 | $X12 = \text{RM}$                                                                      | $\text{RM} = 3.5074$                                                       |

|   |        |        |    |       |        |        |       |    |   |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|---|----|-------|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0      | 0      | 0     | 0  | 0 | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0 | 0  | 0     | 0 | X2  | = | -0.163  | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0 | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.4444 | 0.9444 | 0     | 0  | 0 | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.022 | 0      | 0      | 0     | 0  | 0 | 0  | 0     | 0 | X5  | = | 1.1613  |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0 | 0  | 0     | 0 | X6  | = | -0.2661 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0 | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 5.017 | -1 | 0 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0 | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0 | -1 | 0.287 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0 | 0  | 0     | 1 | X12 | = | 3.50738 |     |

Subject 1, Task 2, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.59 | -0.16 | -0.10 | 0.53 | 75.82  | -0.27 | -0.44 | 0.70 | 3.51 | 0.00 | 0.00 | 3.51 |
| 1.00  | 0.57 | -0.10 | -0.18 | 0.65 | 81.25  | -0.44 | -0.48 | 0.70 | 3.51 | 0.00 | 0.00 | 3.51 |
| 2.00  | 0.71 | -0.18 | -0.15 | 0.69 | 82.80  | -0.48 | -0.50 | 0.70 | 3.51 | 0.00 | 0.00 | 3.51 |
| 3.00  | 0.78 | -0.15 | -0.22 | 0.85 | 90.22  | -0.50 | -0.67 | 1.02 | 5.11 | 0.36 | 1.25 | 3.51 |
| 4.00  | 0.97 | -0.22 | -0.22 | 0.97 | 95.62  | -0.67 | -0.71 | 1.02 | 5.11 | 0.36 | 1.25 | 3.51 |
| 5.00  | 0.99 | -0.22 | -0.24 | 1.01 | 97.17  | -0.71 | -0.73 | 1.02 | 5.11 | 0.36 | 1.25 | 3.51 |
| 6.00  | 1.02 | -0.24 | -0.23 | 1.02 | 97.61  | -0.73 | -0.73 | 1.02 | 5.11 | 0.36 | 1.25 | 3.51 |
| 7.00  | 1.12 | -0.23 | -0.29 | 1.17 | 104.71 | -0.73 | -0.90 | 1.34 | 6.72 | 0.72 | 2.50 | 3.51 |
| 8.00  | 1.28 | -0.29 | -0.30 | 1.29 | 110.02 | -0.90 | -0.95 | 1.34 | 6.72 | 0.72 | 2.50 | 3.51 |
| 9.00  | 1.32 | -0.30 | -0.31 | 1.33 | 111.53 | -0.95 | -0.96 | 1.34 | 6.72 | 0.72 | 2.50 | 3.51 |
| 10.00 | 1.34 | -0.31 | -0.31 | 1.34 | 111.97 | -0.96 | -0.96 | 1.34 | 6.72 | 0.72 | 2.50 | 3.51 |
| 11.00 | 1.44 | -0.31 | -0.36 | 1.49 | 119.07 | -0.96 | -1.13 | 1.66 | 8.33 | 1.07 | 3.74 | 3.51 |
| 12.00 | 1.60 | -0.36 | -0.37 | 1.61 | 124.38 | -1.13 | -1.18 | 1.66 | 8.33 | 1.07 | 3.74 | 3.51 |
| 13.00 | 1.64 | -0.37 | -0.38 | 1.65 | 125.89 | -1.18 | -1.19 | 1.66 | 8.33 | 1.07 | 3.74 | 3.51 |
| 14.00 | 1.66 | -0.38 | -0.38 | 1.66 | 126.33 | -1.19 | -1.19 | 1.66 | 8.33 | 1.07 | 3.74 | 3.51 |
| 15.00 | 1.36 | -0.38 | -0.22 | 1.19 | 105.53 | -1.19 | -0.70 | 0.70 | 3.51 | 0.00 | 0.00 | 3.51 |
| 16.00 | 0.88 | -0.22 | -0.18 | 0.84 | 89.74  | -0.70 | -0.56 | 0.70 | 3.51 | 0.00 | 0.00 | 3.51 |

Subject 2, Task 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|---------|
| 0.5                  | 0                     | 0.0000           | 84                  | 0.8700                                        | 0.8170                           | 4.9257          | 4.0243                      | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 78                  | 0.9500                                        | 0.5730                           | 5.0324          | 2.8835                      | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 77                  | 0.8800                                        | 0.6110                           | 4.9390          | 3.0178                      | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 78                  | 0.9000                                        | 0.6070                           | 4.9657          | 3.0142                      | 0.0000  |
| 2.5                  | 25                    | 0.3583           | 81                  | 0.8900                                        | 0.4460                           | 4.9524          | 2.2088                      | -0.2100 |
| 3.0                  | 25                    | 0.3583           | 94                  | 0.7800                                        | 0.6470                           | 4.8057          | 3.1093                      | -0.4449 |
| 3.5                  | 25                    | 0.3583           | 93                  | 0.8600                                        | 0.8700                           | 4.9124          | 4.2738                      | 0.9971  |
| 4.0                  | 25                    | 0.3583           | 93                  | 0.8500                                        | 0.7870                           | 4.8991          | 3.8556                      | -6.0814 |
| 4.5                  | 25                    | 0.3583           | 97                  | 0.8700                                        | 0.7710                           | 4.9257          | 3.7977                      | -3.0688 |
| 5.0                  | 25                    | 0.3583           | 93                  | 0.8800                                        | 0.9550                           | 4.9390          | 4.7168                      | 0.4465  |
| 5.5                  | 25                    | 0.3583           | 94                  | 0.8800                                        | 0.8100                           | 4.9390          | 4.0006                      | 4.1579  |
| 6.0                  | 25                    | 0.3583           | 96                  | 0.8800                                        | 0.8980                           | 4.9390          | 4.4353                      | 0.6879  |
| 6.5                  | 50                    | 0.7165           | 101                 | 0.8700                                        | 0.9270                           | 4.9257          | 4.5661                      | 2.4419  |
| 7.0                  | 50                    | 0.7165           | 108                 | 0.9000                                        | 1.2370                           | 4.9657          | 6.1426                      | 0.3832  |
| 7.5                  | 50                    | 0.7165           | 106                 | 0.9200                                        | 1.0680                           | 4.9924          | 5.3318                      | 0.6765  |
| 8.0                  | 50                    | 0.7165           | 103                 | 0.9600                                        | 1.1910                           | 5.0457          | 6.0094                      | 0.4126  |
| 8.5                  | 50                    | 0.7165           | 111                 | 0.9600                                        | 1.0380                           | 5.0457          | 5.2374                      | 0.7427  |
| 9.0                  | 50                    | 0.7165           | 108                 | 0.9600                                        | 1.2480                           | 5.0457          | 6.2970                      | 0.3539  |
| 9.5                  | 50                    | 0.7165           | 113                 | 0.9500                                        | 1.2600                           | 5.0324          | 6.3408                      | 0.3465  |
| 10.0                 | 50                    | 0.7165           | 107                 | 0.9700                                        | 1.2160                           | 5.0590          | 6.1518                      | 0.3813  |
| 10.5                 | 75                    | 1.0748           | 121                 | 0.9300                                        | 1.2590                           | 5.0057          | 6.3022                      | 0.6431  |
| 11.0                 | 75                    | 1.0748           | 125                 | 0.9500                                        | 1.3380                           | 5.0324          | 6.7333                      | 0.5112  |
| 11.5                 | 75                    | 1.0748           | 131                 | 1.0200                                        | 1.6620                           | 5.1257          | 8.5188                      | 0.2764  |
| 12.0                 | 75                    | 1.0748           | 130                 | 1.0200                                        | 1.2890                           | 5.1257          | 6.6070                      | 0.5439  |
| 12.5                 | 75                    | 1.0748           | 132                 | 0.9700                                        | 1.4480                           | 5.0590          | 7.3254                      | 0.3989  |
| 13.0                 | 75                    | 1.0748           | 139                 | 1.0600                                        | 1.3260                           | 5.1790          | 6.8673                      | 0.4806  |
| 13.5                 | 75                    | 1.0748           | 144                 | 0.9900                                        | 1.6600                           | 5.0857          | 8.4422                      | 0.2820  |
| 14.0                 | 75                    | 1.0748           | 144                 | 1.0500                                        | 1.5170                           | 5.1657          | 7.8363                      | 0.3353  |
| 14.5                 | 0                     | 0.0000           | 120                 | 1.0300                                        | 1.9050                           | 5.1390          | 9.7898                      | 0.0000  |
| 15.0                 | 0                     | 0.0000           | 117                 | 1.2500                                        | 1.1130                           | 5.4323          | 6.0461                      | 0.0000  |
| 15.5                 | 0                     | 0.0000           | 112                 | 1.2800                                        | 0.8420                           | 5.4722          | 4.6076                      | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 107                 | 1.2500                                        | 0.6600                           | 5.4323          | 3.5853                      | 0.0000  |

Subject 2, Task 2, PWC calculation

| Work Load | HR     | VO2    |
|-----------|--------|--------|
| rest      |        |        |
| 1         | 95     | 0.8877 |
| 2         | 109.75 | 1.1905 |
| 3         | 142.33 | 1.5885 |

Regression Output:

|                     |            |
|---------------------|------------|
| Constant            | -0.441327  |
| Std Err of Y Est    | 0.06733921 |
| R Squared           | 0.98164668 |
| No. of Observations | 3          |
| Degrees of Freedom  | 1          |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.014379 |
| Std Err of Coef. | 0.001966 |

Max. HR 194

PWC = 2.348209

Subject 2, Test 2

| Equation Type      | Equation                                                                               | Equation Parameters                                     |
|--------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------|
| regression<br>i/t  | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$                                    | D= 0.23 $\alpha$ = 0.58                                 |
| balance            | $X1 + X2 = X3 + X4$                                                                    |                                                         |
| regression<br>gain | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$<br>$X4 = \text{Coef} \cdot X5 + C$ | D= 0.72 $\alpha$ = 0.32<br>Coef = 0.0223    C = -1.1613 |
| i/t                |                                                                                        |                                                         |
| balance            | $X4 + X6 = X7 + X8$                                                                    |                                                         |
| gain               | $X9 = Y \cdot X8$                                                                      | Y = 5.0173                                              |
| balance            | $X9 = X10 + X11 + X12$                                                                 |                                                         |
| exogenous          |                                                                                        |                                                         |
| regression         | $X10 = \text{Eff} \cdot X11$                                                           | Eff = 0.2870                                            |
| exogenous          | $X12 = \text{RM}$                                                                      | RM = 3.5562                                             |

|   |        |        |    |       |       |       |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|-------|-------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.1597 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.444 | 0.944 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.022 | 0     | 0     | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 1.1613  |     |
| 0 | 0      | 0      | 0  | 0     | 1     | 0     | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.4167 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1     | -1    | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 5.017 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | -1 | 0.287 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | 1 | X12 | = | 3.55621 |     |



Subject 2, Task 2, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.66 | -0.16 | -0.14 | 0.64 | 80.86  | -0.42 | -0.48 | 0.71 | 3.56 | 0.00 | 0.00 | 3.56 |
| 1.00  | 0.66 | -0.14 | -0.17 | 0.69 | 83.00  | -0.48 | -0.50 | 0.71 | 3.56 | 0.00 | 0.00 | 3.56 |
| 2.00  | 0.71 | -0.17 | -0.16 | 0.70 | 83.62  | -0.50 | -0.51 | 0.71 | 3.56 | 0.00 | 0.00 | 3.56 |
| 3.00  | 0.80 | -0.16 | -0.22 | 0.86 | 90.76  | -0.51 | -0.67 | 1.03 | 5.16 | 0.36 | 1.25 | 3.56 |
| 4.00  | 0.97 | -0.22 | -0.23 | 0.98 | 96.09  | -0.67 | -0.72 | 1.03 | 5.16 | 0.36 | 1.25 | 3.56 |
| 5.00  | 1.01 | -0.23 | -0.24 | 1.02 | 97.61  | -0.72 | -0.74 | 1.03 | 5.16 | 0.36 | 1.25 | 3.56 |
| 6.00  | 1.03 | -0.24 | -0.24 | 1.03 | 98.05  | -0.74 | -0.74 | 1.03 | 5.16 | 0.36 | 1.25 | 3.56 |
| 7.00  | 1.13 | -0.24 | -0.29 | 1.18 | 105.14 | -0.74 | -0.91 | 1.35 | 6.77 | 0.72 | 2.50 | 3.56 |
| 8.00  | 1.29 | -0.29 | -0.30 | 1.30 | 110.45 | -0.91 | -0.95 | 1.35 | 6.77 | 0.72 | 2.50 | 3.56 |
| 9.00  | 1.33 | -0.30 | -0.31 | 1.34 | 111.97 | -0.95 | -0.97 | 1.35 | 6.77 | 0.72 | 2.50 | 3.56 |
| 10.00 | 1.34 | -0.31 | -0.31 | 1.35 | 112.40 | -0.97 | -0.97 | 1.35 | 6.77 | 0.72 | 2.50 | 3.56 |
| 11.00 | 1.45 | -0.31 | -0.37 | 1.50 | 119.50 | -0.97 | -1.14 | 1.67 | 8.38 | 1.07 | 3.74 | 3.56 |
| 12.00 | 1.61 | -0.37 | -0.38 | 1.62 | 124.81 | -1.14 | -1.18 | 1.67 | 8.38 | 1.07 | 3.74 | 3.56 |
| 13.00 | 1.65 | -0.38 | -0.38 | 1.66 | 126.33 | -1.18 | -1.20 | 1.67 | 8.38 | 1.07 | 3.74 | 3.56 |
| 14.00 | 1.67 | -0.38 | -0.38 | 1.67 | 126.76 | -1.20 | -1.20 | 1.67 | 8.38 | 1.07 | 3.74 | 3.56 |
| 15.00 | 1.37 | -0.38 | -0.22 | 1.20 | 105.96 | -1.20 | -0.71 | 0.71 | 3.56 | 0.00 | 0.00 | 3.56 |
| 16.00 | 0.89 | -0.22 | -0.18 | 0.85 | 90.18  | -0.71 | -0.57 | 0.71 | 3.56 | 0.00 | 0.00 | 3.56 |

Subject 3, Task 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|---------|
| 0.5                  | 0                     | 0.0000           | 74                  | 0.7900                                        | 0.3790                           | 4.8191          | 1.8264                      | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 75                  | 0.7600                                        | 0.2860                           | 4.7791          | 1.3668                      | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 74                  | 0.7700                                        | 0.3840                           | 4.7924          | 1.8403                      | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 73                  | 0.7600                                        | 0.3280                           | 4.7791          | 1.5675                      | 0.0000  |
| 2.5                  | 25                    | 0.3583           | 89                  | 0.8100                                        | 0.4910                           | 4.8457          | 2.3793                      | -1.9870 |
| 3.0                  | 25                    | 0.3583           | 92                  | 0.7900                                        | 0.5770                           | 4.8191          | 2.7806                      | 1.6206  |
| 3.5                  | 25                    | 0.3583           | 94                  | 0.7800                                        | 0.7980                           | 4.8057          | 3.8350                      | 0.2809  |
| 4.0                  | 25                    | 0.3583           | 91                  | 0.7800                                        | 0.6820                           | 4.8057          | 3.2775                      | 0.4990  |
| 4.5                  | 25                    | 0.3583           | 98                  | 0.8400                                        | 0.8480                           | 4.8857          | 4.1431                      | 0.2262  |
| 5.0                  | 25                    | 0.3583           | 94                  | 0.8600                                        | 0.7210                           | 4.9124          | 3.5418                      | 0.3647  |
| 5.5                  | 25                    | 0.3583           | 98                  | 0.8600                                        | 0.8300                           | 4.9124          | 4.0773                      | 0.2360  |
| 6.0                  | 25                    | 0.3583           | 95                  | 0.8900                                        | 0.7940                           | 4.9524          | 3.9322                      | 0.2610  |
| 6.5                  | 50                    | 0.7165           | 100                 | 0.8900                                        | 0.8460                           | 4.9524          | 4.1897                      | 0.5633  |
| 7.0                  | 50                    | 0.7165           | 102                 | 0.8800                                        | 1.0160                           | 4.9390          | 5.0181                      | 0.3411  |
| 7.5                  | 50                    | 0.7165           | 105                 | 0.9000                                        | 0.9400                           | 4.9657          | 4.6678                      | 0.4094  |
| 8.0                  | 50                    | 0.7165           | 103                 | 0.9300                                        | 1.0970                           | 5.0057          | 5.4912                      | 0.2784  |
| 8.5                  | 50                    | 0.7165           | 105                 | 0.9500                                        | 1.0360                           | 5.0324          | 5.2135                      | 0.3121  |
| 9.0                  | 50                    | 0.7165           | 105                 | 0.9400                                        | 1.0700                           | 5.0190          | 5.3704                      | 0.2921  |
| 9.5                  | 50                    | 0.7165           | 108                 | 0.9200                                        | 1.1010                           | 4.9924          | 5.4966                      | 0.2778  |
| 10.0                 | 50                    | 0.7165           | 112                 | 0.9300                                        | 1.1140                           | 5.0057          | 5.5763                      | 0.2695  |
| 10.5                 | 75                    | 1.0748           | 116                 | 0.9500                                        | 1.1370                           | 5.0324          | 5.7218                      | 0.4394  |
| 11.0                 | 75                    | 1.0748           | 118                 | 0.9700                                        | 1.3260                           | 5.0590          | 6.7082                      | 0.3131  |
| 11.5                 | 75                    | 1.0748           | 117                 | 0.9900                                        | 1.4210                           | 5.0857          | 7.2267                      | 0.2720  |
| 12.0                 | 75                    | 1.0748           | 125                 | 1.0000                                        | 1.4800                           | 5.0990          | 7.5465                      | 0.2517  |
| 12.5                 | 75                    | 1.0748           | 129                 | 1.0000                                        | 1.5810                           | 5.0990          | 8.0615                      | 0.2246  |
| 13.0                 | 75                    | 1.0748           | 129                 | 1.0200                                        | 1.5990                           | 5.1257          | 8.1959                      | 0.2185  |
| 13.5                 | 75                    | 1.0748           | 126                 | 1.0200                                        | 1.6420                           | 5.1257          | 8.4163                      | 0.2091  |
| 14.0                 | 75                    | 1.0748           | 128                 | 1.0100                                        | 1.6390                           | 5.1123          | 8.3791                      | 0.2106  |
| 14.5                 | 0                     | 0.0000           | 95                  | 1.0200                                        | 1.3060                           | 5.1257          | 6.6941                      | 0.0000  |
| 15.0                 | 0                     | 0.0000           | 90                  | 1.0900                                        | 0.8550                           | 5.2190          | 4.4622                      | 0.0000  |
| 15.5                 | 0                     | 0.0000           | 84                  | 1.1900                                        | 0.6800                           | 5.3523          | 3.6395                      | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 88                  | 1.2000                                        | 0.5530                           | 5.3656          | 2.9672                      | 0.0000  |

Subject 3, Task 2, PWC calculation

| Work Load | HR     | VO2     |
|-----------|--------|---------|
| 1         | 96.25  | 0.79825 |
| 2         | 107.50 | 1.08025 |
| 3         | 128.00 | 1.61525 |

Regression Output:

|                     |            |
|---------------------|------------|
| Constant            | -1.6859046 |
| Std Err of Y Est    | 0.00602938 |
| R Squared           | 0.99989445 |
| No. of Observations | 3          |
| Degrees of Freedom  | 1          |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.025777 |
| Std Err of Coef. | 0.000265 |

Max. HR            191

PWC =            3.23747



## Subject 3, Test 2

| Equation Type | Equation                                    | Equation Parameters |        |             |
|---------------|---------------------------------------------|---------------------|--------|-------------|
| regression    | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.23   | alfa= 0.58  |
| i/t           |                                             |                     |        |             |
| balance       | $X1 + X2 = X3 + X4$                         |                     |        |             |
| regression    | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.72   | alfa= 0.32  |
| gain          | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0258 | C = -1.6859 |
| i/t           |                                             |                     |        |             |
| balance       | $X4 + X6 = X7 + X8$                         |                     |        |             |
| gain          | $X9 = Y * X8$                               | Y =                 | 5.0173 |             |
| balance       | $X9 = X10 + X11 + X12$                      |                     |        |             |
| exogenous     |                                             |                     |        |             |
| regression    | $X10 = \text{Eff} * X11$                    | Eff =               | 0.2870 |             |
| exogenous     | $X12 = \text{RM}$                           | RM =                | 2.2013 |             |

|   |        |        |    |       |       |       |       |    |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|-------|-------|-------|----|----|-------|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.1597 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.444 | 0.944 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.026 | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X5  | = | 1.6859  |     |
| 0 | 0      | 0      | 0  | 0     | 1     | 0     | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.4167 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1     | -1    | -1    | 0  | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 5.017 | -1 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | -1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | -1 | 0.287 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 1 | X12 | = | 2.2013  |     |

Subject 3, Task 2, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.58 | -0.16 | -0.09 | 0.51 | 85.22  | -0.42 | -0.34 | 0.44 | 2.20 | 0.00 | 0.00 | 2.20 |
| 1.00  | 0.44 | -0.09 | -0.11 | 0.46 | 83.22  | -0.34 | -0.32 | 0.44 | 2.20 | 0.00 | 0.00 | 2.20 |
| 2.00  | 0.46 | -0.11 | -0.10 | 0.44 | 82.65  | -0.32 | -0.32 | 0.44 | 2.20 | 0.00 | 0.00 | 2.20 |
| 3.00  | 0.53 | -0.10 | -0.16 | 0.60 | 88.52  | -0.32 | -0.48 | 0.76 | 3.81 | 0.36 | 1.25 | 2.20 |
| 4.00  | 0.70 | -0.16 | -0.17 | 0.71 | 93.04  | -0.48 | -0.53 | 0.76 | 3.81 | 0.36 | 1.25 | 2.20 |
| 5.00  | 0.74 | -0.17 | -0.17 | 0.75 | 94.33  | -0.53 | -0.54 | 0.76 | 3.81 | 0.36 | 1.25 | 2.20 |
| 6.00  | 0.76 | -0.17 | -0.17 | 0.76 | 94.70  | -0.54 | -0.54 | 0.76 | 3.81 | 0.36 | 1.25 | 2.20 |
| 7.00  | 0.86 | -0.17 | -0.23 | 0.91 | 100.84 | -0.54 | -0.71 | 1.08 | 5.41 | 0.72 | 2.50 | 2.20 |
| 8.00  | 1.02 | -0.23 | -0.24 | 1.03 | 105.43 | -0.71 | -0.76 | 1.08 | 5.41 | 0.72 | 2.50 | 2.20 |
| 9.00  | 1.06 | -0.24 | -0.25 | 1.07 | 106.74 | -0.76 | -0.77 | 1.08 | 5.41 | 0.72 | 2.50 | 2.20 |
| 10.00 | 1.07 | -0.25 | -0.25 | 1.08 | 107.12 | -0.77 | -0.78 | 1.08 | 5.41 | 0.72 | 2.50 | 2.20 |
| 11.00 | 1.18 | -0.25 | -0.30 | 1.23 | 113.26 | -0.78 | -0.94 | 1.40 | 7.02 | 1.07 | 3.74 | 2.20 |
| 12.00 | 1.34 | -0.30 | -0.32 | 1.35 | 117.85 | -0.94 | -0.99 | 1.40 | 7.02 | 1.07 | 3.74 | 2.20 |
| 13.00 | 1.38 | -0.32 | -0.32 | 1.39 | 119.16 | -0.99 | -1.00 | 1.40 | 7.02 | 1.07 | 3.74 | 2.20 |
| 14.00 | 1.40 | -0.32 | -0.32 | 1.40 | 119.54 | -1.00 | -1.01 | 1.40 | 7.02 | 1.07 | 3.74 | 2.20 |
| 15.00 | 1.10 | -0.32 | -0.16 | 0.93 | 101.55 | -1.01 | -0.51 | 0.44 | 2.20 | 0.00 | 0.00 | 2.20 |
| 16.00 | 0.62 | -0.16 | -0.12 | 0.58 | 87.89  | -0.51 | -0.37 | 0.44 | 2.20 | 0.00 | 0.00 | 2.20 |

Subject 4, Task 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|---------|
| 0.5                  | 0                     | 0.0000           | 78                  | 0.8800                                        | 0.4870                           | 4.9390          | 2.4053                      | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 99                  | 0.8400                                        | 0.6010                           | 4.8857          | 2.9363                      | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 95                  | 0.8300                                        | 0.6820                           | 4.8724          | 3.3230                      | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 97                  | 0.8700                                        | 0.5920                           | 4.9257          | 2.9160                      | 0.0000  |
| 2.5                  | 25                    | 0.3583           | 107                 | 0.8900                                        | 0.6710                           | 4.9524          | 3.3230                      | -0.8656 |
| 3.0                  | 25                    | 0.3583           | 110                 | 0.8500                                        | 0.8590                           | 4.8991          | 4.2083                      | 0.7600  |
| 3.5                  | 25                    | 0.3583           | 108                 | 0.8600                                        | 0.9850                           | 4.9124          | 4.8387                      | 0.3252  |
| 4.0                  | 25                    | 0.3583           | 112                 | 0.8700                                        | 1.0780                           | 4.9257          | 5.3099                      | 0.2277  |
| 4.5                  | 25                    | 0.3583           | 110                 | 0.9100                                        | 1.0510                           | 4.9790          | 5.2330                      | 0.2395  |
| 5.0                  | 25                    | 0.3583           | 110                 | 0.8800                                        | 1.1100                           | 4.9390          | 5.4823                      | 0.2053  |
| 5.5                  | 25                    | 0.3583           | 109                 | 0.8900                                        | 1.1380                           | 4.9524          | 5.6358                      | 0.1887  |
| 6.0                  | 25                    | 0.3583           | 110                 | 0.8900                                        | 1.0300                           | 4.9524          | 5.1009                      | 0.2626  |
| 6.5                  | 50                    | 0.7165           | 118                 | 0.9100                                        | 1.1270                           | 4.9790          | 5.6114                      | 0.4726  |
| 7.0                  | 50                    | 0.7165           | 119                 | 0.8800                                        | 1.2600                           | 4.9390          | 6.2232                      | 0.3367  |
| 7.5                  | 50                    | 0.7165           | 122                 | 0.9300                                        | 1.4200                           | 5.0057          | 7.1081                      | 0.2378  |
| 8.0                  | 50                    | 0.7165           | 124                 | 0.9600                                        | 1.3980                           | 5.0457          | 7.0539                      | 0.2422  |
| 8.5                  | 50                    | 0.7165           | 124                 | 0.9400                                        | 1.4150                           | 5.0190          | 7.1019                      | 0.2383  |
| 9.0                  | 50                    | 0.7165           | 127                 | 0.9600                                        | 1.4990                           | 5.0457          | 7.5635                      | 0.2066  |
| 9.5                  | 50                    | 0.7165           | 127                 | 0.9500                                        | 1.5060                           | 5.0324          | 7.5787                      | 0.2057  |
| 10.0                 | 50                    | 0.7165           | 127                 | 0.9300                                        | 1.4520                           | 5.0057          | 7.2683                      | 0.2258  |
| 10.5                 | 75                    | 1.0748           | 135                 | 0.9700                                        | 1.6090                           | 5.0590          | 8.1399                      | 0.2915  |
| 11.0                 | 75                    | 1.0748           | 136                 | 0.9600                                        | 1.7070                           | 5.0457          | 8.6130                      | 0.2584  |
| 11.5                 | 75                    | 1.0748           | 142                 | 0.9700                                        | 1.8430                           | 5.0590          | 9.3238                      | 0.2207  |
| 12.0                 | 75                    | 1.0748           | 144                 | 1.0200                                        | 1.9300                           | 5.1257          | 9.8925                      | 0.1976  |
| 12.5                 | 75                    | 1.0748           | 144                 | 1.0100                                        | 1.8610                           | 5.1123          | 9.5140                      | 0.2124  |
| 13.0                 | 75                    | 1.0748           | 147                 | 1.0300                                        | 1.9350                           | 5.1390          | 9.9439                      | 0.1957  |
| 13.5                 | 75                    | 1.0748           | 146                 | 1.0400                                        | 2.0430                           | 5.1523          | 10.5262                     | 0.1770  |
| 14.0                 | 75                    | 1.0748           | 150                 | 1.0700                                        | 2.0780                           | 5.1923          | 10.7896                     | 0.1696  |
| 14.5                 | 0                     | 0.0000           | 129                 | 0.9800                                        | 1.6490                           | 5.0723          | 8.3643                      | 0.0000  |
| 15.0                 | 0                     | 0.0000           | 120                 | 1.0600                                        | 1.1710                           | 5.1790          | 6.0646                      | 0.0000  |
| 15.5                 | 0                     | 0.0000           | 116                 | 1.1200                                        | 0.9260                           | 5.2590          | 4.8698                      | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 113                 | 1.1400                                        | 0.7230                           | 5.2856          | 3.8215                      | 0.0000  |

Subject 4, Task 2, PWC calculation

| Work Load | HR     | VO2    |
|-----------|--------|--------|
| 1         | 109.75 | 1.0823 |
| 2         | 126.25 | 1.4680 |
| 3         | 146.75 | 1.9793 |

Regression Output:

|                     |            |
|---------------------|------------|
| Constant            | -1.5867105 |
| Std Err of Y Est    | 0.01166424 |
| R Squared           | 0.99966401 |
| No. of Observations | 3          |
| Degrees of Freedom  | 1          |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.024271 |
| Std Err of Coef. | 0.000445 |

Max. HR      193

PWC =      3.097596

Subject 4, Test 2

|               |                                                     |                                          |
|---------------|-----------------------------------------------------|------------------------------------------|
| Equation Type | Equation                                            | Equation Parameters                      |
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | $D = 0.23 \quad \alpha = 0.58$           |
| i/t           |                                                     |                                          |
| balance       | $X1 + X2 = X3 + X4$                                 |                                          |
| regression    | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | $D = 0.72 \quad \alpha = 0.32$           |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | $\text{Coef} = 0.0243 \quad C = -1.5867$ |
| i/t           |                                                     |                                          |
| balance       | $X4 + X6 = X7 + X8$                                 |                                          |
| gain          | $X9 = Y \cdot X8$                                   | $Y = 5.0173$                             |
| balance       | $X9 = X10 + X11 + X12$                              |                                          |
| exogenous     |                                                     |                                          |
| regression    | $X10 = \text{Eff} \cdot X11$                        | $\text{Eff} = 0.2870$                    |
| exogenous     | $X12 = \text{RM}$                                   | $\text{RM} = 3.3787$                     |

|   |        |        |    |       |       |       |       |    |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|-------|-------|-------|----|----|-------|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.1614 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.444 | 0.944 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.024 | 0     | 0     | 0     | 0  | 0  | 0     | 0 | X5  | = | 1.58671 |     |
| 0 | 0      | 0      | 0  | 0     | 1     | 0     | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.4452 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1     | -1    | -1    | 0  | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 5.017 | -1 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | -1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | -1 | 0.287 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0  | 0     | 1 | X12 | = | 3.37865 |     |



Subject 4, Task 2, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.67 | -0.16 | -0.14 | 0.65 | 91.95  | -0.45 | -0.47 | 0.67 | 3.38 | 0.00 | 0.00 | 3.38 |
| 1.00  | 0.65 | -0.14 | -0.16 | 0.67 | 92.79  | -0.47 | -0.48 | 0.67 | 3.38 | 0.00 | 0.00 | 3.38 |
| 2.00  | 0.68 | -0.16 | -0.15 | 0.67 | 93.02  | -0.48 | -0.48 | 0.67 | 3.38 | 0.00 | 0.00 | 3.38 |
| 3.00  | 0.77 | -0.15 | -0.21 | 0.83 | 99.50  | -0.48 | -0.65 | 0.99 | 4.99 | 0.36 | 1.25 | 3.38 |
| 4.00  | 0.94 | -0.21 | -0.22 | 0.95 | 104.37 | -0.65 | -0.70 | 0.99 | 4.99 | 0.36 | 1.25 | 3.38 |
| 5.00  | 0.97 | -0.22 | -0.23 | 0.98 | 105.76 | -0.70 | -0.71 | 0.99 | 4.99 | 0.36 | 1.25 | 3.38 |
| 6.00  | 0.99 | -0.23 | -0.23 | 0.99 | 106.15 | -0.71 | -0.71 | 0.99 | 4.99 | 0.36 | 1.25 | 3.38 |
| 7.00  | 1.09 | -0.23 | -0.28 | 1.15 | 112.67 | -0.71 | -0.88 | 1.31 | 6.59 | 0.72 | 2.50 | 3.38 |
| 8.00  | 1.25 | -0.28 | -0.30 | 1.27 | 117.55 | -0.88 | -0.93 | 1.31 | 6.59 | 0.72 | 2.50 | 3.38 |
| 9.00  | 1.29 | -0.30 | -0.30 | 1.30 | 118.95 | -0.93 | -0.94 | 1.31 | 6.59 | 0.72 | 2.50 | 3.38 |
| 10.00 | 1.31 | -0.30 | -0.30 | 1.31 | 119.35 | -0.94 | -0.94 | 1.31 | 6.59 | 0.72 | 2.50 | 3.38 |
| 11.00 | 1.41 | -0.30 | -0.36 | 1.47 | 125.87 | -0.94 | -1.11 | 1.63 | 8.20 | 1.07 | 3.74 | 3.38 |
| 12.00 | 1.57 | -0.36 | -0.37 | 1.59 | 130.75 | -1.11 | -1.16 | 1.63 | 8.20 | 1.07 | 3.74 | 3.38 |
| 13.00 | 1.61 | -0.37 | -0.37 | 1.62 | 132.14 | -1.16 | -1.17 | 1.63 | 8.20 | 1.07 | 3.74 | 3.38 |
| 14.00 | 1.63 | -0.37 | -0.38 | 1.63 | 132.54 | -1.17 | -1.17 | 1.63 | 8.20 | 1.07 | 3.74 | 3.38 |
| 15.00 | 1.33 | -0.38 | -0.21 | 1.17 | 113.43 | -1.17 | -0.68 | 0.67 | 3.38 | 0.00 | 0.00 | 3.38 |
| 16.00 | 0.85 | -0.21 | -0.17 | 0.81 | 98.92  | -0.68 | -0.54 | 0.67 | 3.38 | 0.00 | 0.00 | 3.38 |

Subject 5, Task 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff     |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|---------|
| 0.5                  | 0                     | 0.0000           | 89                  | 0.8500                                        | 0.3570                           | 4.8991          | 1.7490                      | 0.0000  |
| 1.0                  | 0                     | 0.0000           | 96                  | 0.8700                                        | 0.3600                           | 4.9257          | 1.7733                      | 0.0000  |
| 1.5                  | 0                     | 0.0000           | 98                  | 0.8700                                        | 0.3840                           | 4.9257          | 1.8915                      | 0.0000  |
| 2.0                  | 0                     | 0.0000           | 92                  | 0.8400                                        | 0.3860                           | 4.8857          | 1.8859                      | 0.0000  |
| 2.5                  | 25                    | 0.3583           | 113                 | 0.9000                                        | 0.3570                           | 4.9657          | 1.7728                      | -0.6074 |
| 3.0                  | 25                    | 0.3583           | 115                 | 0.8400                                        | 0.6430                           | 4.8857          | 3.1415                      | 0.4599  |
| 3.5                  | 25                    | 0.3583           | 114                 | 0.8700                                        | 0.7390                           | 4.9257          | 3.6401                      | 0.2804  |
| 4.0                  | 25                    | 0.3583           | 113                 | 0.9000                                        | 0.6900                           | 4.9657          | 3.4263                      | 0.3368  |
| 4.5                  | 25                    | 0.3583           | 109                 | 0.9200                                        | 0.7610                           | 4.9924          | 3.7992                      | 0.2494  |
| 5.0                  | 25                    | 0.3583           | 112                 | 0.9400                                        | 0.6860                           | 5.0190          | 3.4430                      | 0.3316  |
| 5.5                  | 25                    | 0.3583           | 115                 | 0.9300                                        | 0.7290                           | 5.0057          | 3.6491                      | 0.2785  |
| 6.0                  | 25                    | 0.3583           | 103                 | 0.9500                                        | 0.7500                           | 5.0324          | 3.7743                      | 0.2538  |
| 6.5                  | 50                    | 0.7165           | 125                 | 0.9300                                        | 0.7730                           | 5.0057          | 3.8694                      | 0.6238  |
| 7.0                  | 50                    | 0.7165           | 121                 | 0.9300                                        | 0.9540                           | 5.0057          | 4.7754                      | 0.3487  |
| 7.5                  | 50                    | 0.7165           | 122                 | 0.9700                                        | 1.0880                           | 5.0590          | 5.5042                      | 0.2574  |
| 8.0                  | 50                    | 0.7165           | 122                 | 1.0100                                        | 1.0490                           | 5.1123          | 5.3628                      | 0.2712  |
| 8.5                  | 50                    | 0.7165           | 122                 | 1.0000                                        | 1.0400                           | 5.0990          | 5.3030                      | 0.2775  |
| 9.0                  | 50                    | 0.7165           | 123                 | 1.0000                                        | 1.1000                           | 5.0990          | 5.6089                      | 0.2481  |
| 9.5                  | 50                    | 0.7165           | 118                 | 1.0000                                        | 1.1240                           | 5.0990          | 5.7313                      | 0.2380  |
| 10.0                 | 50                    | 0.7165           | 122                 | 0.9900                                        | 1.0860                           | 5.0857          | 5.5230                      | 0.2557  |
| 10.5                 | 75                    | 1.0748           | 127                 | 0.9700                                        | 1.2550                           | 5.0590          | 6.3491                      | 0.3287  |
| 11.0                 | 75                    | 1.0748           | 132                 | 0.9700                                        | 1.4080                           | 5.0590          | 7.1231                      | 0.2658  |
| 11.5                 | 75                    | 1.0748           | 139                 | 1.0000                                        | 1.6420                           | 5.0990          | 8.3726                      | 0.2030  |
| 12.0                 | 75                    | 1.0748           | 143                 | 1.0800                                        | 1.6000                           | 5.2056          | 8.3290                      | 0.2047  |
| 12.5                 | 75                    | 1.0748           | 141                 | 1.0500                                        | 1.6110                           | 5.1657          | 8.3219                      | 0.2050  |
| 13.0                 | 75                    | 1.0748           | 144                 | 1.0500                                        | 1.7820                           | 5.1657          | 9.2052                      | 0.1754  |
| 13.5                 | 75                    | 1.0748           | 148                 | 1.0900                                        | 1.6940                           | 5.2190          | 8.8409                      | 0.1865  |
| 14.0                 | 75                    | 1.0748           | 148                 | 1.1100                                        | 1.6370                           | 5.2456          | 8.5871                      | 0.1951  |
| 14.5                 | 0                     | 0.0000           | 120                 | 1.0400                                        | 1.3520                           | 5.1523          | 6.9659                      | 0.0000  |
| 15.0                 | 0                     | 0.0000           | 107                 | 1.1200                                        | 0.8440                           | 5.2590          | 4.4386                      | 0.0000  |
| 15.5                 | 0                     | 0.0000           | 100                 | 1.2400                                        | 0.5070                           | 5.4189          | 2.7474                      | 0.0000  |
| 16.0                 | 0                     | 0.0000           | 90                  | 1.2200                                        | 0.3670                           | 5.3923          | 1.9790                      | 0.0000  |

Subject 5, Task 2, PWC calculation

| Work Load | HR     | VO2    |
|-----------|--------|--------|
| 1         | 109.75 | 0.7315 |
| 2         | 121.25 | 1.0875 |
| 3         | 145.25 | 1.681  |

Regression Output:

|                     |            |
|---------------------|------------|
| Constant            | -2.1492296 |
| Std Err of Y Est    | 0.0387387  |
| R Squared           | 0.99673889 |
| No. of Observations | 3          |
| Degrees of Freedom  | 1          |

|                  |          |
|------------------|----------|
| X Coefficient(s) | 0.026439 |
| Std Err of Coef. | 0.001512 |

Max. HR            194

PWC =            2.979944



Subject 5, Test 2

| Equation Type             | Equation                                                               | Equation Parameters                                                        |
|---------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------|
| regression<br>i/t         | $X1 = -1/D (\alpha X2 + (1-\alpha) X3)$                                | $D = 0.23 \quad \alpha = 0.58$                                             |
| balance                   | $X1 + X2 = X3 + X4$                                                    |                                                                            |
| regression<br>gain<br>i/t | $X4 = -1/D (\alpha X6 + (1-\alpha) X7)$<br>$X4 = \text{Coef} * X5 + C$ | $D = 0.72 \quad \alpha = 0.32$<br>$\text{Coef} = 0.0264 \quad C = -2.1492$ |
| balance                   | $X4 + X6 = X7 + X8$                                                    |                                                                            |
| gain                      | $X9 = Y * X8$                                                          | $Y = 5.0173$                                                               |
| balance                   | $X9 = X10 + X11 + X12$                                                 |                                                                            |
| exogenous                 |                                                                        |                                                                            |
| regression                | $X10 = \text{Eff} * X11$                                               | $\text{Eff} = 0.2870$                                                      |
| exogenous                 | $X12 = \text{RM}$                                                      | $\text{RM} = 2.0043$                                                       |

|   |        |        |    |       |       |       |       |    |   |    |       |     |   |         |     |
|---|--------|--------|----|-------|-------|-------|-------|----|---|----|-------|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0     | 0     | 0     | 0  | 0 | 0  | 0     | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0 | 0  | 0     | X2  | = | -0.1614 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0     | 0     | 0     | 0  | 0 | 0  | 0     | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.444 | 0.944 | 0     | 0  | 0 | 0  | 0     | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.026 | 0     | 0     | 0     | 0  | 0 | 0  | 0     | X5  | = | 2.14923 |     |
| 0 | 0      | 0      | 0  | 0     | 1     | 0     | 0     | 0  | 0 | 0  | 0     | X6  | = | -0.4452 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1     | -1    | -1    | 0  | 0 | 0  | 0     | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 5.017 | -1 | 0 | 0  | 0     | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | -1 | 1 | 1  | 1     | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 1 | 0  | 0     | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0 | -1 | 0.287 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0     | 0     | 0     | 0  | 0 | 0  | 1     | X12 | = | 2.00432 |     |

Subject 5, Task 2, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.58 | -0.16 | -0.09 | 0.51 | 100.66 | -0.45 | -0.33 | 0.40 | 2.00 | 0.00 | 0.00 | 2.00 |
| 1.00  | 0.42 | -0.09 | -0.10 | 0.43 | 97.62  | -0.33 | -0.30 | 0.40 | 2.00 | 0.00 | 0.00 | 2.00 |
| 2.00  | 0.42 | -0.10 | -0.09 | 0.41 | 96.75  | -0.30 | -0.29 | 0.40 | 2.00 | 0.00 | 0.00 | 2.00 |
| 3.00  | 0.50 | -0.09 | -0.15 | 0.56 | 102.38 | -0.29 | -0.45 | 0.72 | 3.61 | 0.36 | 1.25 | 2.00 |
| 4.00  | 0.66 | -0.15 | -0.16 | 0.67 | 106.76 | -0.45 | -0.50 | 0.72 | 3.61 | 0.36 | 1.25 | 2.00 |
| 5.00  | 0.70 | -0.16 | -0.16 | 0.71 | 108.01 | -0.50 | -0.51 | 0.72 | 3.61 | 0.36 | 1.25 | 2.00 |
| 6.00  | 0.72 | -0.16 | -0.16 | 0.72 | 108.37 | -0.51 | -0.52 | 0.72 | 3.61 | 0.36 | 1.25 | 2.00 |
| 7.00  | 0.82 | -0.16 | -0.22 | 0.87 | 114.35 | -0.52 | -0.68 | 1.04 | 5.22 | 0.72 | 2.50 | 2.00 |
| 8.00  | 0.98 | -0.22 | -0.23 | 0.99 | 118.83 | -0.68 | -0.73 | 1.04 | 5.22 | 0.72 | 2.50 | 2.00 |
| 9.00  | 1.02 | -0.23 | -0.24 | 1.03 | 120.11 | -0.73 | -0.74 | 1.04 | 5.22 | 0.72 | 2.50 | 2.00 |
| 10.00 | 1.04 | -0.24 | -0.24 | 1.04 | 120.47 | -0.74 | -0.75 | 1.04 | 5.22 | 0.72 | 2.50 | 2.00 |
| 11.00 | 1.14 | -0.24 | -0.29 | 1.19 | 126.46 | -0.75 | -0.91 | 1.36 | 6.82 | 1.07 | 3.74 | 2.00 |
| 12.00 | 1.30 | -0.29 | -0.31 | 1.31 | 130.94 | -0.91 | -0.96 | 1.36 | 6.82 | 1.07 | 3.74 | 2.00 |
| 13.00 | 1.34 | -0.31 | -0.31 | 1.35 | 132.22 | -0.96 | -0.97 | 1.36 | 6.82 | 1.07 | 3.74 | 2.00 |
| 14.00 | 1.36 | -0.31 | -0.31 | 1.36 | 132.59 | -0.97 | -0.98 | 1.36 | 6.82 | 1.07 | 3.74 | 2.00 |
| 15.00 | 1.06 | -0.31 | -0.15 | 0.89 | 115.04 | -0.98 | -0.48 | 0.40 | 2.00 | 0.00 | 0.00 | 2.00 |
| 16.00 | 0.58 | -0.15 | -0.11 | 0.54 | 101.73 | -0.48 | -0.34 | 0.40 | 2.00 | 0.00 | 0.00 | 2.00 |

## APPENDIX D

### Task 3 Data

Subject 1, Task 3, Trial 1, experimentally collected data

| Time<br>min<br>**** | Freq.<br>Lif/min<br>**** | Load<br>Kg<br>**** | Type<br>**** | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>**** | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|---------------------|--------------------------|--------------------|--------------|---------------|------------------|---------------------|----------------------|-------------|----------------|---------------|--------|
| 0.5                 |                          |                    | Sit          | 0.0000        | 0.0000           | 83                  | 0.7700               | 0.4730      | 4.3965         | 2.0795        | 0.0000 |
| 1.0                 |                          |                    | Sit          | 0.0000        | 0.0000           | 87                  | 0.7800               | 0.5210      | 4.4605         | 2.3239        | 0.0000 |
| 1.5                 |                          |                    | Sit          | 0.0000        | 0.0000           | 86                  | 0.8000               | 0.5490      | 4.4978         | 2.4693        | 0.0000 |
| 2.0                 |                          |                    | Sit          | 0.0000        | 0.0000           | 88                  | 0.8400               | 0.3600      | 4.2459         | 1.5285        | 0.0000 |
| 2.5                 |                          |                    | Sit          | 0.0000        | 0.0000           | 99                  | 0.8100               | 0.5320      | 4.4752         | 2.3808        | 0.0000 |
| 3.0                 |                          |                    | Sit          | 0.0000        | 0.0000           | 91                  | 0.8700               | 0.5240      | 4.4645         | 2.3394        | 0.0000 |
| 3.5                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 112                 | 0.8300               | 0.7590      | 4.7777         | 3.6263        | 0.0379 |
| 4.0                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 104                 | 0.8200               | 0.9520      | 5.0350         | 4.7933        | 0.0195 |
| 4.5                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 102                 | 0.8000               | 1.0210      | 5.1270         | 5.2347        | 0.0164 |
| 5.0                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 101                 | 0.7800               | 1.1910      | 5.3536         | 6.3761        | 0.0117 |
| 5.5                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 104                 | 0.7600               | 1.1810      | 5.3403         | 6.3069        | 0.0119 |
| 6.0                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 103                 | 0.7500               | 1.1040      | 5.2376         | 5.7823        | 0.0138 |
| 6.5                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 104                 | 0.7400               | 1.2210      | 5.3936         | 6.5856        | 0.0111 |
| 7.0                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 106                 | 0.7500               | 1.1820      | 5.3416         | 6.3138        | 0.0119 |
| 7.5                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 106                 | 0.7600               | 1.1790      | 5.3376         | 6.2930        | 0.0120 |
| 8.0                 | 6                        | 5                  | Squat        | 3.2500        | 0.0466           | 107                 | 0.7600               | 1.2020      | 5.3683         | 6.4527        | 0.0115 |
| 8.5                 |                          |                    | Sit          | 0.0000        | 0.0000           | 104                 | 0.7700               | 1.2870      | 5.4816         | 7.0548        | 0.0000 |
| 9.0                 |                          |                    | Sit          | 0.0000        | 0.0000           | 93                  | 0.8000               | 0.9410      | 5.0204         | 4.7242        | 0.0000 |
| 9.5                 |                          |                    | Sit          | 0.0000        | 0.0000           | 86                  | 0.8300               | 0.5480      | 4.4965         | 2.4641        | 0.0000 |
| 10.0                |                          |                    | Sit          | 0.0000        | 0.0000           | 83                  | 0.8200               | 0.5290      | 4.4712         | 2.3652        | 0.0000 |
| 10.5                |                          |                    | Sit          | 0.0000        | 0.0000           | 82                  | 0.7800               | 0.4670      | 4.3885         | 2.0494        | 0.0000 |
| 11.0                |                          |                    | Sit          | 0.0000        | 0.0000           | 87                  | 0.7900               | 0.4310      | 4.3405         | 1.8708        | 0.0000 |
| 11.5                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 114                 | 0.8000               | 0.7560      | 4.7737         | 3.6090        | 0.0269 |
| 12.0                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 96                  | 0.8600               | 0.7020      | 4.7018         | 3.3006        | 0.0360 |
| 12.5                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 102                 | 0.8200               | 0.7260      | 4.7338         | 3.4367        | 0.0313 |
| 13.0                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 99                  | 0.8400               | 0.6540      | 4.6378         | 3.0331        | 0.0509 |
| 13.5                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 94                  | 0.8200               | 0.8370      | 4.8817         | 4.0860        | 0.0194 |
| 14.0                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 95                  | 0.8100               | 0.6500      | 4.6325         | 3.0111        | 0.0527 |
| 14.5                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 103                 | 0.7700               | 0.7550      | 4.7724         | 3.6032        | 0.0271 |
| 15.0                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 96                  | 0.8100               | 0.6950      | 4.6924         | 3.2612        | 0.0376 |
| 15.5                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 96                  | 0.8000               | 0.9450      | 5.0257         | 4.7493        | 0.0139 |
| 16.0                | 4                        | 5                  | Arm          | 2.3000        | 0.0330           | 95                  | 0.8000               | 0.7720      | 4.7951         | 3.7018        | 0.0250 |
| 16.5                |                          |                    | Sit          | 0.0000        | 0.0000           | 89                  | 0.8000               | 0.8900      | 4.9524         | 4.4076        | 0.0000 |
| 17.0                |                          |                    | Sit          | 0.0000        | 0.0000           | 83                  | 0.8100               | 0.7180      | 4.7231         | 3.3912        | 0.0000 |
| 17.5                |                          |                    | Sit          | 0.0000        | 0.0000           | 82                  | 0.7600               | 0.6550      | 4.6391         | 3.0386        | 0.0000 |
| 18.0                |                          |                    | Sit          | 0.0000        | 0.0000           | 76                  | 0.8100               | 0.4110      | 4.3139         | 1.7730        | 0.0000 |
| 18.5                |                          |                    | Sit          | 0.0000        | 0.0000           | 83                  | 0.8300               | 0.5970      | 4.5618         | 2.7234        | 0.0000 |
| 19.0                |                          |                    | Sit          | 0.0000        | 0.0000           | 77                  | 0.8000               | 0.3780      | 4.2699         | 1.6140        | 0.0000 |
| 19.5                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 100                 | 0.8400               | 0.7370      | 4.7484         | 3.4996        | 0.1388 |
| 20.0                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 102                 | 0.8500               | 1.0150      | 5.1190         | 5.1958        | 0.0517 |
| 20.5                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 107                 | 0.8000               | 1.1660      | 5.3203         | 6.2034        | 0.0377 |
| 21.0                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 103                 | 0.7400               | 1.3990      | 5.6309         | 7.8776        | 0.0260 |
| 21.5                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 109                 | 0.7800               | 1.3430      | 5.5562         | 7.4620        | 0.0281 |
| 22.0                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 109                 | 0.7900               | 1.3920      | 5.6215         | 7.8252        | 0.0262 |
| 22.5                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 107                 | 0.8000               | 1.3640      | 5.5842         | 7.6169        | 0.0273 |
| 23.0                | 6                        | 15                 | Squat        | 9.7600        | 0.1399           | 107                 | 0.7800               | 1.1310      | 5.2736         | 5.9645        | 0.0403 |

|      |   |    |       |        |        |     |        |        |        |        |        |
|------|---|----|-------|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 6 | 15 | Squat | 9.7600 | 0.1399 | 110 | 0.7700 | 1.4120 | 5.6482 | 7.9753 | 0.0255 |
| 24.0 | 6 | 15 | Squat | 9.7600 | 0.1399 | 111 | 0.8100 | 1.3790 | 5.6042 | 7.7282 | 0.0267 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 104 | 0.7900 | 1.3340 | 5.5442 | 7.3960 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 89  | 0.8200 | 0.8990 | 4.9644 | 4.4630 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 81  | 0.8100 | 0.6530 | 4.6364 | 3.0276 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 81  | 0.8200 | 0.4460 | 4.3605 | 1.9448 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 83  | 0.8200 | 0.5380 | 4.4832 | 2.4119 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 86  | 0.7600 | 0.7610 | 4.7804 | 3.6379 | 0.0000 |



Subject 1, Task 3, Trial 2, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.8000       | 0.5900       | 4.8324         | 2.8511        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.8000       | 0.6100       | 4.8324         | 2.9478        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.8300       | 0.5490       | 4.8724         | 2.6749        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 72          | 0.8000       | 0.4590       | 4.8324         | 2.2181        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.8300       | 0.4400       | 4.8724         | 2.1439        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.7700       | 0.5060       | 4.7924         | 2.4250        | 0.0000 |
| 3.5         | 4                | 5          | Squat | 2.1700        | 0.0311           | 105         | 0.8300       | 0.5850       | 4.8724         | 2.8503        | 0.0850 |
| 4.0         | 4                | 5          | Squat | 2.1700        | 0.0311           | 99          | 0.8500       | 1.0270       | 4.8991         | 5.0313        | 0.0122 |
| 4.5         | 4                | 5          | Squat | 2.1700        | 0.0311           | 99          | 0.8300       | 1.0580       | 4.8724         | 5.1550        | 0.0116 |
| 5.0         | 4                | 5          | Squat | 2.1700        | 0.0311           | 97          | 0.8300       | 1.1820       | 4.8724         | 5.7592        | 0.0095 |
| 5.5         | 4                | 5          | Squat | 2.1700        | 0.0311           | 100         | 0.8100       | 1.1870       | 4.8457         | 5.7519        | 0.0095 |
| 6.0         | 4                | 5          | Squat | 2.1700        | 0.0311           | 95          | 0.7700       | 0.9440       | 4.7924         | 4.5240        | 0.0152 |
| 6.5         | 4                | 5          | Squat | 2.1700        | 0.0311           | 93          | 0.8100       | 0.9970       | 4.8457         | 4.8312        | 0.0133 |
| 7.0         | 4                | 5          | Squat | 2.1700        | 0.0311           | 100         | 0.8100       | 0.9390       | 4.8457         | 4.5501        | 0.0151 |
| 7.5         | 4                | 5          | Squat | 2.1700        | 0.0311           | 97          | 0.8300       | 0.9820       | 4.8724         | 4.7847        | 0.0135 |
| 8.0         | 4                | 5          | Squat | 2.1700        | 0.0311           | 95          | 0.8000       | 0.9690       | 4.8324         | 4.6826        | 0.0141 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.7700       | 1.0830       | 4.7924         | 5.1902        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.8600       | 0.7510       | 4.9124         | 3.6892        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.8300       | 0.5460       | 4.8724         | 2.6603        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 71          | 0.7900       | 0.4870       | 4.8191         | 2.3469        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 67          | 0.8100       | 0.4280       | 4.8457         | 2.0740        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.7700       | 0.4390       | 4.7924         | 2.1039        | 0.0000 |
| 11.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 100         | 0.8400       | 0.7680       | 4.8857         | 3.7522        | 0.0828 |
| 12.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 106         | 0.9100       | 0.7250       | 4.9790         | 3.6098        | 0.0939 |
| 12.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 104         | 0.8600       | 0.8080       | 4.9124         | 3.9692        | 0.0701 |
| 13.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 96          | 0.8200       | 0.8820       | 4.8591         | 4.2857        | 0.0573 |
| 13.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 94          | 0.8200       | 0.9330       | 4.8591         | 4.5335        | 0.0501 |
| 14.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 100         | 0.8100       | 0.9420       | 4.8457         | 4.5647        | 0.0494 |
| 14.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 93          | 0.8100       | 0.8730       | 4.8457         | 4.2303        | 0.0592 |
| 15.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 97          | 0.8100       | 1.0610       | 4.8457         | 5.1413        | 0.0384 |
| 15.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 98          | 0.8400       | 1.0020       | 4.8857         | 4.8955        | 0.0424 |
| 16.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 95          | 0.8200       | 0.9220       | 4.8591         | 4.4801        | 0.0515 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.7500       | 1.0890       | 4.7658         | 5.1899        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 72          | 0.8000       | 0.6150       | 4.8324         | 2.9719        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 69          | 0.7800       | 0.4860       | 4.8057         | 2.3356        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 71          | 0.7800       | 0.4390       | 4.8057         | 2.1097        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.7800       | 0.4670       | 4.8057         | 2.2443        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.8000       | 0.5050       | 4.8324         | 2.4404        | 0.0000 |
| 19.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.8500       | 0.5700       | 4.8991         | 2.7925        | 0.3786 |
| 20.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.9200       | 0.6950       | 4.9924         | 3.4697        | 0.1009 |
| 20.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 100         | 0.9000       | 0.7830       | 4.9657         | 3.8881        | 0.0694 |
| 21.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.8500       | 0.8630       | 4.8991         | 4.2279        | 0.0554 |
| 21.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.8200       | 0.9810       | 4.8591         | 4.7667        | 0.0420 |
| 22.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 100         | 0.8400       | 1.0260       | 4.8857         | 5.0127        | 0.0378 |
| 22.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.7900       | 0.7890       | 4.8191         | 3.8022        | 0.0742 |
| 23.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.8000       | 0.8850       | 4.8324         | 4.2767        | 0.0538 |

|      |   |    |       |        |        |    |        |        |        |        |        |
|------|---|----|-------|--------|--------|----|--------|--------|--------|--------|--------|
| 23.5 | 4 | 15 | Squat | 6.5000 | 0.0931 | 98 | 0.8200 | 1.0610 | 4.8591 | 5.1555 | 0.0357 |
| 24.0 | 4 | 15 | Squat | 6.5000 | 0.0931 | 98 | 0.8200 | 1.1070 | 4.8591 | 5.3790 | 0.0329 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 88 | 0.7900 | 1.2630 | 4.8191 | 6.0865 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 77 | 0.8700 | 0.8500 | 4.9257 | 4.1869 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 73 | 0.8200 | 0.7660 | 4.8591 | 3.7220 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 74 | 0.8600 | 0.5500 | 4.9124 | 2.7018 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 75 | 0.8100 | 0.5320 | 4.8457 | 2.5779 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 76 | 0.8500 | 0.5050 | 4.8991 | 2.4740 | 0.0000 |

Subject 1, Task 3, Trial 3, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | **** | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit  | 0.0000        | 0.0000           | 68          | 0.8500       | 0.6430       | 4.8991         | 3.1501        | 0.0000 |
| 1.0         |                  |            | Sit  | 0.0000        | 0.0000           | 68          | 0.8200       | 0.4190       | 4.8591         | 2.0359        | 0.0000 |
| 1.5         |                  |            | Sit  | 0.0000        | 0.0000           | 71          | 0.8100       | 0.3880       | 4.8457         | 1.8801        | 0.0000 |
| 2.0         |                  |            | Sit  | 0.0000        | 0.0000           | 70          | 0.8200       | 0.5590       | 4.8591         | 2.7162        | 0.0000 |
| 2.5         |                  |            | Sit  | 0.0000        | 0.0000           | 73          | 0.8100       | 0.5460       | 4.8457         | 2.6458        | 0.0000 |
| 3.0         |                  |            | Sit  | 0.0000        | 0.0000           | 71          | 0.8500       | 0.3940       | 4.8991         | 1.9302        | 0.0000 |
| 3.5         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 92          | 0.8400       | 0.7020       | 4.8857         | 3.4298        | 0.1685 |
| 4.0         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 93          | 0.9100       | 0.8670       | 4.9790         | 4.3168        | 0.0841 |
| 4.5         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 94          | 0.8100       | 1.0460       | 4.8457         | 5.0686        | 0.0591 |
| 5.0         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 101         | 0.7800       | 1.2150       | 4.8057         | 5.8390        | 0.0452 |
| 5.5         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 98          | 0.7900       | 1.2160       | 4.8191         | 5.8600        | 0.0450 |
| 6.0         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 91          | 0.8000       | 1.1330       | 4.8324         | 5.4751        | 0.0509 |
| 6.5         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 93          | 0.8000       | 1.1040       | 4.8324         | 5.3350        | 0.0534 |
| 7.0         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 94          | 0.8100       | 1.1050       | 4.8457         | 5.3545        | 0.0531 |
| 7.5         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 96          | 0.8000       | 1.0610       | 4.8324         | 5.1272        | 0.0577 |
| 8.0         | 6                | 15         | Arm  | 10.4000       | 0.1490           | 97          | 0.8300       | 1.1900       | 4.8724         | 5.7981        | 0.0458 |
| 8.5         |                  |            | Sit  | 0.0000        | 0.0000           | 81          | 0.8000       | 1.4440       | 4.8324         | 6.9780        | 0.0000 |
| 9.0         |                  |            | Sit  | 0.0000        | 0.0000           | 70          | 0.8500       | 0.6110       | 4.8991         | 2.9933        | 0.0000 |
| 9.5         |                  |            | Sit  | 0.0000        | 0.0000           | 73          | 0.8400       | 0.6090       | 4.8857         | 2.9754        | 0.0000 |
| 10.0        |                  |            | Sit  | 0.0000        | 0.0000           | 71          | 0.8400       | 0.6420       | 4.8857         | 3.1366        | 0.0000 |
| 10.5        |                  |            | Sit  | 0.0000        | 0.0000           | 70          | 0.8700       | 0.4750       | 4.9257         | 2.3397        | 0.0000 |
| 11.0        |                  |            | Sit  | 0.0000        | 0.0000           | 70          | 0.8600       | 0.5280       | 4.9124         | 2.5937        | 0.0000 |
| 11.5        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 89          | 0.8900       | 0.6620       | 4.9524         | 3.2785        | 0.0597 |
| 12.0        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 86          | 0.9000       | 0.6140       | 4.9657         | 3.0489        | 0.0825 |
| 12.5        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 84          | 0.8800       | 0.7900       | 4.9390         | 3.9018        | 0.0342 |
| 13.0        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 88          | 0.8900       | 0.7610       | 4.9524         | 3.7688        | 0.0376 |
| 13.5        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 85          | 0.8600       | 0.7470       | 4.9124         | 3.6695        | 0.0406 |
| 14.0        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 87          | 0.8600       | 0.8260       | 4.9124         | 4.0576        | 0.0309 |
| 14.5        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 87          | 0.8400       | 0.7420       | 4.8857         | 3.6252        | 0.0422 |
| 15.0        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 82          | 0.8600       | 0.7580       | 4.9124         | 3.7236        | 0.0389 |
| 15.5        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 83          | 0.8500       | 0.7780       | 4.8991         | 3.8115        | 0.0364 |
| 16.0        | 6                | 5          | Arm  | 3.4700        | 0.0497           | 83          | 0.8500       | 0.7830       | 4.8991         | 3.8360        | 0.0358 |
| 16.5        |                  |            | Sit  | 0.0000        | 0.0000           | 79          | 0.8400       | 1.0140       | 4.8857         | 4.9541        | 0.0000 |
| 17.0        |                  |            | Sit  | 0.0000        | 0.0000           | 62          | 0.8700       | 0.5960       | 4.9257         | 2.9357        | 0.0000 |
| 17.5        |                  |            | Sit  | 0.0000        | 0.0000           | 64          | 0.8900       | 0.4910       | 4.9524         | 2.4316        | 0.0000 |
| 18.0        |                  |            | Sit  | 0.0000        | 0.0000           | 66          | 0.8800       | 0.4360       | 4.9390         | 2.1534        | 0.0000 |
| 18.5        |                  |            | Sit  | 0.0000        | 0.0000           | 63          | 0.8500       | 0.3860       | 4.8991         | 1.8910        | 0.0000 |
| 19.0        |                  |            | Sit  | 0.0000        | 0.0000           | 71          | 0.8300       | 0.4230       | 4.8724         | 2.0610        | 0.0000 |



## Subject 1, Test 3

| Equation Type     | Equation                                            | Equation Parameters |        |       |         |
|-------------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression<br>i/t | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.23   | alfa= | 0.58    |
| balance           | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| regression        | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.72   | alfa= | 0.32    |
| gain<br>i/t       | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0349 | C =   | -2.3197 |
| balance           | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| gain              | $X9 = Y \cdot X8$                                   | Y =                 | 4.8850 |       |         |
| balance           | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| exogenous         |                                                     |                     |        |       |         |
| regression        | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0337 |       |         |
| exogenous         | $X12 = \text{RM}$                                   | RM =                | 2.4011 |       |         |

|   |        |        |    |       |         |         |       |    |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|----|-------|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.44444 | 0.94444 | 0     | 0  | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.035 | 0       | 0       | 0     | 0  | 0  | 0     | 0 | X5  | = | 2.31969 |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0  | 0     | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | -1    | 0  | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.885 | -1 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | -1 | 0.034 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 1 | X12 | = | 2.40105 |     |

Subject 1, Task 3, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.67 | -0.19 | -0.10 | 0.58 | 83.13  | -0.48 | -0.39 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 1.00  | 0.49 | -0.10 | -0.13 | 0.52 | 81.29  | -0.39 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 2.00  | 0.52 | -0.13 | -0.11 | 0.50 | 80.76  | -0.36 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 3.00  | 0.49 | -0.11 | -0.12 | 0.49 | 80.61  | -0.36 | -0.35 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 4.00  | 0.59 | -0.12 | -0.16 | 0.63 | 84.64  | -0.35 | -0.50 | 0.78 | 3.83 | 0.05 | 1.38 | 2.40 |
| 5.00  | 0.73 | -0.16 | -0.18 | 0.74 | 87.71  | -0.50 | -0.55 | 0.78 | 3.83 | 0.05 | 1.38 | 2.40 |
| 6.00  | 0.77 | -0.18 | -0.18 | 0.77 | 88.59  | -0.55 | -0.56 | 0.78 | 3.83 | 0.05 | 1.38 | 2.40 |
| 7.00  | 0.78 | -0.18 | -0.18 | 0.78 | 88.84  | -0.56 | -0.56 | 0.78 | 3.83 | 0.05 | 1.38 | 2.40 |
| 8.00  | 0.78 | -0.18 | -0.18 | 0.78 | 88.91  | -0.56 | -0.56 | 0.78 | 3.83 | 0.05 | 1.38 | 2.40 |
| 9.00  | 0.69 | -0.18 | -0.13 | 0.64 | 84.86  | -0.56 | -0.41 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 10.00 | 0.55 | -0.13 | -0.12 | 0.53 | 81.78  | -0.41 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 11.00 | 0.51 | -0.12 | -0.11 | 0.50 | 80.90  | -0.37 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 12.00 | 0.56 | -0.11 | -0.15 | 0.60 | 83.53  | -0.36 | -0.46 | 0.70 | 3.41 | 0.03 | 0.98 | 2.40 |
| 13.00 | 0.66 | -0.15 | -0.16 | 0.67 | 85.64  | -0.46 | -0.49 | 0.70 | 3.41 | 0.03 | 0.98 | 2.40 |
| 14.00 | 0.69 | -0.16 | -0.16 | 0.69 | 86.25  | -0.49 | -0.50 | 0.70 | 3.41 | 0.03 | 0.98 | 2.40 |
| 15.00 | 0.70 | -0.16 | -0.16 | 0.70 | 86.42  | -0.50 | -0.50 | 0.70 | 3.41 | 0.03 | 0.98 | 2.40 |
| 16.00 | 0.70 | -0.16 | -0.16 | 0.70 | 86.47  | -0.50 | -0.50 | 0.70 | 3.41 | 0.03 | 0.98 | 2.40 |
| 17.00 | 0.63 | -0.16 | -0.13 | 0.60 | 83.60  | -0.50 | -0.40 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 18.00 | 0.53 | -0.13 | -0.12 | 0.52 | 81.42  | -0.40 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 19.00 | 0.50 | -0.12 | -0.11 | 0.50 | 80.80  | -0.37 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 20.00 | 0.77 | -0.11 | -0.26 | 0.92 | 92.86  | -0.36 | -0.81 | 1.37 | 6.70 | 0.14 | 4.15 | 2.40 |
| 21.00 | 1.21 | -0.26 | -0.30 | 1.24 | 102.06 | -0.81 | -0.94 | 1.37 | 6.70 | 0.14 | 4.15 | 2.40 |
| 22.00 | 1.32 | -0.30 | -0.31 | 1.33 | 104.69 | -0.94 | -0.97 | 1.37 | 6.70 | 0.14 | 4.15 | 2.40 |
| 23.00 | 1.36 | -0.31 | -0.31 | 1.36 | 105.44 | -0.97 | -0.98 | 1.37 | 6.70 | 0.14 | 4.15 | 2.40 |
| 24.00 | 1.37 | -0.31 | -0.32 | 1.37 | 105.65 | -0.98 | -0.99 | 1.37 | 6.70 | 0.14 | 4.15 | 2.40 |
| 25.00 | 1.09 | -0.32 | -0.16 | 0.94 | 93.48  | -0.99 | -0.53 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 26.00 | 0.65 | -0.16 | -0.13 | 0.62 | 84.24  | -0.53 | -0.41 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 27.00 | 0.54 | -0.13 | -0.12 | 0.53 | 81.61  | -0.41 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 28.00 | 0.50 | -0.12 | -0.12 | 0.50 | 80.85  | -0.37 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 29.00 | 0.50 | -0.12 | -0.11 | 0.49 | 80.64  | -0.36 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 30.00 | 0.49 | -0.11 | -0.11 | 0.49 | 80.57  | -0.36 | -0.35 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 31.00 | 0.55 | -0.11 | -0.15 | 0.59 | 83.28  | -0.35 | -0.45 | 0.69 | 3.36 | 0.03 | 0.92 | 2.40 |
| 32.00 | 0.65 | -0.15 | -0.15 | 0.66 | 85.33  | -0.45 | -0.48 | 0.69 | 3.36 | 0.03 | 0.92 | 2.40 |
| 33.00 | 0.68 | -0.15 | -0.16 | 0.68 | 85.92  | -0.48 | -0.49 | 0.69 | 3.36 | 0.03 | 0.92 | 2.40 |
| 34.00 | 0.68 | -0.16 | -0.16 | 0.68 | 86.08  | -0.49 | -0.49 | 0.69 | 3.36 | 0.03 | 0.92 | 2.40 |
| 35.00 | 0.69 | -0.16 | -0.16 | 0.69 | 86.13  | -0.49 | -0.49 | 0.69 | 3.36 | 0.03 | 0.92 | 2.40 |
| 36.00 | 0.63 | -0.16 | -0.12 | 0.59 | 83.43  | -0.49 | -0.39 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 37.00 | 0.53 | -0.12 | -0.12 | 0.52 | 81.37  | -0.39 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 38.00 | 0.50 | -0.12 | -0.11 | 0.50 | 80.78  | -0.37 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 39.00 | 0.69 | -0.11 | -0.22 | 0.80 | 89.30  | -0.36 | -0.68 | 1.12 | 5.45 | 0.10 | 2.95 | 2.40 |
| 40.00 | 1.00 | -0.22 | -0.24 | 1.02 | 95.83  | -0.68 | -0.77 | 1.12 | 5.45 | 0.10 | 2.95 | 2.40 |
| 41.00 | 1.08 | -0.24 | -0.25 | 1.09 | 97.69  | -0.77 | -0.79 | 1.12 | 5.45 | 0.10 | 2.95 | 2.40 |
| 42.00 | 1.11 | -0.25 | -0.26 | 1.11 | 98.22  | -0.79 | -0.80 | 1.12 | 5.45 | 0.10 | 2.95 | 2.40 |
| 43.00 | 1.11 | -0.26 | -0.26 | 1.11 | 98.37  | -0.80 | -0.80 | 1.12 | 5.45 | 0.10 | 2.95 | 2.40 |
| 44.00 | 0.92 | -0.26 | -0.15 | 0.81 | 89.73  | -0.80 | -0.48 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 45.00 | 0.61 | -0.15 | -0.13 | 0.58 | 83.17  | -0.48 | -0.39 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |

|       |      |       |       |      |        |       |       |      |      |      |      |      |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 46.00 | 0.53 | -0.13 | -0.12 | 0.52 | 81.30  | -0.39 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 47.00 | 0.68 | -0.12 | -0.22 | 0.78 | 88.91  | -0.36 | -0.66 | 1.08 | 5.26 | 0.09 | 2.77 | 2.40 |
| 48.00 | 0.97 | -0.22 | -0.24 | 0.99 | 94.92  | -0.66 | -0.74 | 1.08 | 5.26 | 0.09 | 2.77 | 2.40 |
| 49.00 | 1.04 | -0.24 | -0.25 | 1.05 | 96.64  | -0.74 | -0.77 | 1.08 | 5.26 | 0.09 | 2.77 | 2.40 |
| 50.00 | 1.07 | -0.25 | -0.25 | 1.07 | 97.13  | -0.77 | -0.77 | 1.08 | 5.26 | 0.09 | 2.77 | 2.40 |
| 51.00 | 1.07 | -0.25 | -0.25 | 1.08 | 97.27  | -0.77 | -0.77 | 1.08 | 5.26 | 0.09 | 2.77 | 2.40 |
| 52.00 | 0.89 | -0.25 | -0.15 | 0.79 | 89.16  | -0.77 | -0.47 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 53.00 | 0.60 | -0.15 | -0.13 | 0.58 | 83.01  | -0.47 | -0.39 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 54.00 | 0.53 | -0.13 | -0.12 | 0.52 | 81.25  | -0.39 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 55.00 | 0.50 | -0.12 | -0.11 | 0.50 | 80.75  | -0.36 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 56.00 | 0.49 | -0.11 | -0.11 | 0.49 | 80.61  | -0.36 | -0.35 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 57.00 | 0.49 | -0.11 | -0.11 | 0.49 | 80.57  | -0.35 | -0.35 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 58.00 | 0.79 | -0.11 | -0.27 | 0.95 | 93.59  | -0.35 | -0.84 | 1.43 | 6.98 | 0.15 | 4.43 | 2.40 |
| 59.00 | 1.26 | -0.27 | -0.31 | 1.29 | 103.45 | -0.84 | -0.97 | 1.43 | 6.98 | 0.15 | 4.43 | 2.40 |
| 60.00 | 1.37 | -0.31 | -0.33 | 1.39 | 106.27 | -0.97 | -1.01 | 1.43 | 6.98 | 0.15 | 4.43 | 2.40 |
| 61.00 | 1.42 | -0.33 | -0.33 | 1.42 | 107.07 | -1.01 | -1.02 | 1.43 | 6.98 | 0.15 | 4.43 | 2.40 |
| 62.00 | 1.42 | -0.33 | -0.33 | 1.43 | 107.30 | -1.02 | -1.03 | 1.43 | 6.98 | 0.15 | 4.43 | 2.40 |
| 63.00 | 1.13 | -0.33 | -0.17 | 0.97 | 94.33  | -1.03 | -0.55 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 64.00 | 0.66 | -0.17 | -0.13 | 0.63 | 84.49  | -0.55 | -0.41 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 65.00 | 0.55 | -0.13 | -0.12 | 0.53 | 81.67  | -0.41 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 66.00 | 0.60 | -0.12 | -0.17 | 0.65 | 85.22  | -0.37 | -0.52 | 0.80 | 3.93 | 0.05 | 1.48 | 2.40 |
| 67.00 | 0.75 | -0.17 | -0.18 | 0.76 | 88.28  | -0.52 | -0.56 | 0.80 | 3.93 | 0.05 | 1.48 | 2.40 |
| 68.00 | 0.79 | -0.18 | -0.18 | 0.79 | 89.16  | -0.56 | -0.57 | 0.80 | 3.93 | 0.05 | 1.48 | 2.40 |
| 69.00 | 0.80 | -0.18 | -0.18 | 0.80 | 89.41  | -0.57 | -0.58 | 0.80 | 3.93 | 0.05 | 1.48 | 2.40 |
| 70.00 | 0.80 | -0.18 | -0.19 | 0.80 | 89.48  | -0.58 | -0.58 | 0.80 | 3.93 | 0.05 | 1.48 | 2.40 |
| 71.00 | 0.71 | -0.19 | -0.13 | 0.65 | 85.15  | -0.58 | -0.42 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 72.00 | 0.55 | -0.13 | -0.12 | 0.54 | 81.86  | -0.42 | -0.37 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |
| 73.00 | 0.51 | -0.12 | -0.11 | 0.50 | 80.93  | -0.37 | -0.36 | 0.49 | 2.40 | 0.00 | 0.00 | 2.40 |



Subject 2, Task 3, Trial 1, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.8600       | 0.5560       | 4.9124         | 2.7313        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 57          | 0.9100       | 0.4260       | 4.9790         | 2.1211        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 63          | 0.8400       | 0.4550       | 4.8857         | 2.2230        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.8500       | 0.4080       | 4.8991         | 1.9988        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 65          | 0.8300       | 0.4020       | 4.8724         | 1.9587        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 59          | 0.8300       | 0.3650       | 4.8724         | 1.7784        | 0.0000 |
| 3.5         | 6                | 15         | Squat | 9.7600        | 0.1399           | 91          | 0.7800       | 0.4660       | 4.8057         | 2.2395        | 0.9492 |
| 4.0         | 6                | 15         | Squat | 9.7600        | 0.1399           | 93          | 0.7700       | 0.8900       | 4.7924         | 4.2652        | 0.0745 |
| 4.5         | 6                | 15         | Squat | 9.7600        | 0.1399           | 91          | 0.7400       | 0.9810       | 4.7524         | 4.6621        | 0.0615 |
| 5.0         | 6                | 15         | Squat | 9.7600        | 0.1399           | 93          | 0.7300       | 1.3060       | 4.7391         | 6.1893        | 0.0368 |
| 5.5         | 6                | 15         | Squat | 9.7600        | 0.1399           | 91          | 0.7400       | 1.0260       | 4.7524         | 4.8760        | 0.0562 |
| 6.0         | 6                | 15         | Squat | 9.7600        | 0.1399           | 89          | 0.7600       | 1.3520       | 4.7791         | 6.4613        | 0.0343 |
| 6.5         | 6                | 15         | Squat | 9.7600        | 0.1399           | 98          | 0.7300       | 1.2130       | 4.7391         | 5.7485        | 0.0416 |
| 7.0         | 6                | 15         | Squat | 9.7600        | 0.1399           | 90          | 0.7900       | 1.0910       | 4.8191         | 5.2576        | 0.0487 |
| 7.5         |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.7600       | 1.5180       | 4.7791         | 7.2546        | 0.0000 |
| 8.0         |                  |            | Sit   | 0.0000        | 0.0000           | 65          | 0.8500       | 0.9110       | 4.8991         | 4.4630        | 0.0000 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 62          | 0.9000       | 0.6390       | 4.9657         | 3.1731        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 62          | 0.9600       | 0.5740       | 5.0457         | 2.8962        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 63          | 0.9800       | 0.4570       | 5.0723         | 2.3181        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 60          | 0.9500       | 0.4700       | 5.0324         | 2.3652        | 0.0000 |
| 10.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 78          | 0.9900       | 0.5460       | 5.0857         | 2.7768        | 0.0624 |
| 11.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 83          | 0.9600       | 0.5450       | 5.0457         | 2.7499        | 0.0659 |
| 11.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 83          | 0.9200       | 0.5920       | 4.9924         | 2.9555        | 0.0459 |
| 12.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 86          | 0.8800       | 0.6970       | 4.9390         | 3.4425        | 0.0267 |
| 12.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 87          | 0.8700       | 0.7610       | 4.9257         | 3.7485        | 0.0211 |
| 13.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 86          | 0.8700       | 0.7990       | 4.9257         | 3.9356        | 0.0188 |
| 13.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 87          | 0.8700       | 0.7300       | 4.9257         | 3.5958        | 0.0236 |
| 14.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 92          | 0.8400       | 0.9240       | 4.8857         | 4.5144        | 0.0139 |
| 14.5        |                  |            | Sit   | 0.0000        | 0.0000           | 65          | 0.8200       | 0.8590       | 4.8591         | 4.1739        | 0.0000 |
| 15.0        |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.8400       | 0.4800       | 4.8857         | 2.3451        | 0.0000 |
| 15.5        |                  |            | Sit   | 0.0000        | 0.0000           | 69          | 0.8600       | 0.4610       | 4.9124         | 2.2646        | 0.0000 |
| 16.0        |                  |            | Sit   | 0.0000        | 0.0000           | 70          | 0.8600       | 0.4170       | 4.9124         | 2.0485        | 0.0000 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 70          | 0.8700       | 0.4230       | 4.9257         | 2.0836        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 70          | 0.8800       | 0.4140       | 4.9390         | 2.0448        | 0.0000 |
| 17.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 74          | 0.8400       | 0.5130       | 4.8857         | 2.5064        | 0.1455 |
| 18.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 86          | 0.8800       | 0.5780       | 4.9390         | 2.8548        | 0.0573 |
| 18.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 81          | 0.8700       | 0.6070       | 4.9257         | 2.9899        | 0.0464 |
| 19.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 79          | 0.8800       | 0.6340       | 4.9390         | 3.1314        | 0.0387 |
| 19.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 79          | 0.8400       | 0.4840       | 4.8857         | 2.3647        | 0.3888 |
| 20.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 80          | 0.8200       | 0.6120       | 4.8591         | 2.9737        | 0.0475 |
| 20.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 78          | 0.8400       | 0.6360       | 4.8857         | 3.1073        | 0.0398 |
| 21.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 84          | 0.8200       | 0.7010       | 4.8591         | 3.4062        | 0.0293 |
| 21.5        |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.7500       | 0.8100       | 4.7658         | 3.8603        | 0.0000 |
| 22.0        |                  |            | Sit   | 0.0000        | 0.0000           | 66          | 0.8200       | 0.6230       | 4.8591         | 3.0272        | 0.0000 |
| 22.5        |                  |            | Sit   | 0.0000        | 0.0000           | 63          | 0.8500       | 0.4810       | 4.8991         | 2.3564        | 0.0000 |
| 23.0        |                  |            | Sit   | 0.0000        | 0.0000           | 65          | 0.8600       | 0.4280       | 4.9124         | 2.1025        | 0.0000 |

|      |     |        |        |    |        |        |        |        |        |
|------|-----|--------|--------|----|--------|--------|--------|--------|--------|
| 23.5 | Sit | 0.0000 | 0.0000 | 69 | 0.8700 | 0.4300 | 4.9257 | 2.1181 | 0.0000 |
| 24.0 | Sit | 0.0000 | 0.0000 | 63 | 0.8700 | 0.4510 | 4.9257 | 2.2215 | 0.0000 |

Subject 2, Task 3, Trial 2, experimentally collected data

| Time<br>min<br>**** | Freq.<br>Lif/min<br>**** | Load<br>Kg<br>**** | Type<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>**** | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|---------------------|--------------------------|--------------------|--------------|-----------------------|------------------|---------------------|----------------------|-------------|----------------|---------------|--------|
| 0.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 72                  | 0.9100               | 0.5820      | 4.9790         | 2.8978        | 0.0000 |
| 1.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 65                  | 0.9100               | 0.4830      | 4.9790         | 2.4049        | 0.0000 |
| 1.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 63                  | 0.9100               | 0.4320      | 4.9790         | 2.1509        | 0.0000 |
| 2.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 64                  | 0.9100               | 0.3970      | 4.9790         | 1.9767        | 0.0000 |
| 2.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 63                  | 0.8800               | 0.3480      | 4.9390         | 1.7188        | 0.0000 |
| 3.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 63                  | 0.9000               | 0.4170      | 4.9657         | 2.0707        | 0.0000 |
| 3.5                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 83                  | 0.8500               | 0.4670      | 4.8991         | 2.2879        | 21.786 |
| 4.0                 | 6                        | 15                 | Arm          | 10.4000               | 0.1490           | 92                  | 0.8500               | 0.8450      | 4.8991         | 4.1397        | 0.0801 |
| 4.5                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 87                  | 0.8500               | 0.9580      | 4.8991         | 4.6933        | 0.0624 |
| 5.0                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 91                  | 0.8500               | 1.0350      | 4.8991         | 5.0705        | 0.0539 |
| 5.5                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 87                  | 0.8700               | 1.0940      | 4.9257         | 5.3887        | 0.0484 |
| 6.0                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 85                  | 0.8600               | 0.9570      | 4.9124         | 4.7011        | 0.0622 |
| 6.5                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 92                  | 0.8500               | 1.2190      | 4.8991         | 5.9719        | 0.0408 |
| 7.0                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 88                  | 0.8900               | 1.0550      | 4.9524         | 5.2248        | 0.0511 |
| 7.5                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 95                  | 0.8800               | 1.0580      | 4.9390         | 5.2255        | 0.0511 |
| 8.0                 | 6                        | 15                 | Arm          | 10.5000               | 0.1505           | 83                  | 0.8500               | 1.1390      | 4.8991         | 5.5800        | 0.0456 |
| 8.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 79                  | 0.8600               | 1.2620      | 4.9124         | 6.1994        | 0.0000 |
| 9.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.9500               | 0.8510      | 5.0324         | 4.2825        | 0.0000 |
| 9.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 63                  | 1.0100               | 0.5800      | 5.1123         | 2.9652        | 0.0000 |
| 10.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 60                  | 0.9700               | 0.5470      | 5.0590         | 2.7673        | 0.0000 |
| 10.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 67                  | 1.0200               | 0.5480      | 5.1257         | 2.8089        | 0.0000 |
| 11.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 67                  | 0.9800               | 0.4870      | 5.0723         | 2.4702        | 0.0000 |
| 11.5                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 79                  | 0.9400               | 0.6330      | 5.0190         | 3.1770        | 0.0499 |
| 12.0                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 80                  | 0.9900               | 0.6590      | 5.0857         | 3.3515        | 0.0425 |
| 12.5                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 75                  | 1.0200               | 0.6500      | 5.1257         | 3.3317        | 0.0432 |
| 13.0                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 73                  | 0.9900               | 0.6300      | 5.0857         | 3.2040        | 0.0486 |
| 13.5                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 75                  | 0.9400               | 0.6200      | 5.0190         | 3.1118        | 0.0534 |
| 14.0                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 80                  | 0.8700               | 0.6920      | 4.9257         | 3.4086        | 0.0405 |
| 14.5                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 81                  | 0.8900               | 0.6810      | 4.9524         | 3.3726        | 0.0417 |
| 15.0                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 74                  | 0.8700               | 0.7240      | 4.9257         | 3.5662        | 0.0359 |
| 15.5                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 83                  | 0.8500               | 0.5800      | 4.8991         | 2.8414        | 0.0752 |
| 16.0                | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 72                  | 0.8500               | 0.6220      | 4.8991         | 3.0472        | 0.0574 |
| 16.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 77                  | 0.8200               | 0.8380      | 4.8591         | 4.0719        | 0.0000 |
| 17.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 66                  | 0.8200               | 0.6060      | 4.8591         | 2.9446        | 0.0000 |
| 17.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 61                  | 0.8600               | 0.3650      | 4.9124         | 1.7930        | 0.0000 |
| 18.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 64                  | 0.8700               | 0.3760      | 4.9257         | 1.8521        | 0.0000 |
| 18.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 63                  | 0.8800               | 0.3370      | 4.9390         | 1.6645        | 0.0000 |
| 19.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.8500               | 0.3550      | 4.8991         | 1.7392        | 0.0000 |
| 19.5                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 95                  | 0.8200               | 0.7340      | 4.8591         | 3.5666        | 0.0694 |
| 20.0                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 92                  | 0.8500               | 0.8550      | 4.8991         | 4.1887        | 0.0474 |
| 20.5                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 94                  | 0.8500               | 0.8540      | 4.8991         | 4.1838        | 0.0475 |
| 21.0                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 87                  | 0.8000               | 0.8740      | 4.8324         | 4.2235        | 0.0466 |
| 21.5                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 86                  | 0.8100               | 0.9600      | 4.8457         | 4.6519        | 0.0384 |
| 22.0                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 92                  | 0.7800               | 0.9600      | 4.8057         | 4.6135        | 0.0390 |
| 22.5                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 88                  | 0.8000               | 1.0330      | 4.8324         | 4.9919        | 0.0336 |
| 23.0                | 4                        | 15                 | Squat        | 6.5000                | 0.0931           | 88                  | 0.7700               | 0.9160      | 4.7924         | 4.3898        | 0.0430 |

|      |   |    |       |        |        |    |        |        |        |        |        |
|------|---|----|-------|--------|--------|----|--------|--------|--------|--------|--------|
| 23.5 | 4 | 15 | Squat | 6.5000 | 0.0931 | 92 | 0.7900 | 0.9470 | 4.8191 | 4.5637 | 0.0398 |
| 24.0 | 4 | 15 | Squat | 6.5000 | 0.0931 | 92 | 0.8300 | 1.0450 | 4.8724 | 5.0916 | 0.0325 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 77 | 0.7900 | 0.9800 | 4.8191 | 4.7227 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 67 | 0.8900 | 0.7040 | 4.9524 | 3.4865 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 67 | 0.8900 | 0.5050 | 4.9524 | 2.5009 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 63 | 0.9300 | 0.4250 | 5.0057 | 2.1274 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 68 | 0.8800 | 0.3390 | 4.9390 | 1.6743 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 69 | 0.8700 | 0.3670 | 4.9257 | 1.8077 | 0.0000 |



Subject 2, Task 3, Trial 3, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 60          | 0.7900       | 1.1390       | 4.8191         | 5.4889        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 59          | 0.9300       | 0.4960       | 5.0057         | 2.4828        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 59          | 0.8700       | 0.4630       | 4.9257         | 2.2806        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 60          | 0.9100       | 0.4120       | 4.9790         | 2.0514        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 61          | 0.9000       | 0.4250       | 4.9657         | 2.1104        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 59          | 0.9200       | 0.3790       | 4.9924         | 1.8921        | 0.0000 |
| 3.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 93          | 0.8300       | 0.4840       | 4.8724         | 2.3582        | 0.6793 |
| 4.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 85          | 0.8700       | 0.6000       | 4.9257         | 2.9554        | 0.1336 |
| 4.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 83          | 0.8900       | 0.6800       | 4.9524         | 3.3676        | 0.0859 |
| 5.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 85          | 0.8400       | 0.6980       | 4.8857         | 3.4102        | 0.0829 |
| 5.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 80          | 0.8300       | 0.6910       | 4.8724         | 3.3668        | 0.0860 |
| 6.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 83          | 0.8600       | 0.7860       | 4.9124         | 3.8611        | 0.0602 |
| 6.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 82          | 0.8700       | 0.7430       | 4.9257         | 3.6598        | 0.0686 |
| 7.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 82          | 0.8300       | 0.7480       | 4.8724         | 3.6445        | 0.0693 |
| 7.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 88          | 0.8200       | 0.7470       | 4.8591         | 3.6297        | 0.0700 |
| 8.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 82          | 0.8500       | 0.6850       | 4.8991         | 3.3558        | 0.0868 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.7900       | 0.9550       | 4.8191         | 4.6022        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 63          | 0.8200       | 0.6760       | 4.8591         | 3.2847        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.8800       | 0.5290       | 4.9390         | 2.6128        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.9100       | 0.5600       | 4.9790         | 2.7883        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 63          | 0.9500       | 0.4130       | 5.0324         | 2.0784        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.9500       | 0.3670       | 5.0324         | 1.8469        | 0.0000 |
| 11.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 89          | 0.9100       | 0.5060       | 4.9790         | 2.5194        | 0.1293 |
| 12.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 86          | 0.9600       | 0.7340       | 5.0457         | 3.7035        | 0.0302 |
| 12.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 87          | 0.9200       | 0.8140       | 4.9924         | 4.0638        | 0.0245 |
| 13.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 79          | 0.9100       | 0.8150       | 4.9790         | 4.0579        | 0.0245 |
| 13.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 82          | 0.9100       | 0.8390       | 4.9790         | 4.1774        | 0.0231 |
| 14.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 85          | 0.8500       | 0.7810       | 4.8991         | 3.8262        | 0.0279 |
| 14.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 88          | 0.8400       | 0.8310       | 4.8857         | 4.0600        | 0.0245 |
| 15.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 88          | 0.8600       | 0.8670       | 4.9124         | 4.2590        | 0.0222 |
| 15.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 84          | 0.8200       | 0.8280       | 4.8591         | 4.0233        | 0.0250 |
| 16.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 89          | 0.8400       | 0.9090       | 4.8857         | 4.4411        | 0.0204 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.8300       | 0.9690       | 4.8724         | 4.7213        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 64          | 0.8700       | 0.6310       | 4.9257         | 3.1081        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 61          | 0.9100       | 0.4230       | 4.9790         | 2.1061        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 62          | 0.9000       | 0.3810       | 4.9657         | 1.8919        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 62          | 0.8900       | 0.3760       | 4.9524         | 1.8621        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 67          | 0.9300       | 0.3660       | 5.0057         | 1.8321        | 0.0000 |



## Subject 2, Test 3

| Equation Type | Equation                                | Equation Parameters |        |       |         |
|---------------|-----------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha X2 + (1-\alpha) X3)$ | D=                  | 0.23   | alfa= | 0.58    |
| i/t           |                                         |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                     |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha X6 + (1-\alpha) X7)$ | D=                  | 0.72   | alfa= | 0.32    |
| gain          | $X4 = \text{Coef} X5 + C$               | Coef =              | 0.0293 | C =   | -1.9650 |
| i/t           |                                         |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                     |                     |        |       |         |
| gain          | $X9 = Y X8$                             | Y =                 | 4.9222 |       |         |
| balance       | $X9 = X10 + X11 + X12$                  |                     |        |       |         |
| exogenous     |                                         |                     |        |       |         |
| regression    | $X10 = \text{Eff} X11$                  | Eff =               | 0.0427 |       |         |
| exogenous     | $X12 = \text{RM}$                       | RM =                | 2.1680 |       |         |

|   |        |        |    |       |        |        |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.4444 | 0.9444 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 1.965   |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.922 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.043 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | 1 | X12 | = | 2.168   |     |

Subject 2, Task 3, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.56 | -0.16 | -0.09 | 0.49 | 83.95  | -0.39 | -0.34 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 1.00  | 0.43 | -0.09 | -0.11 | 0.46 | 82.63  | -0.34 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 2.00  | 0.46 | -0.11 | -0.10 | 0.44 | 82.25  | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 3.00  | 0.43 | -0.10 | -0.10 | 0.44 | 82.14  | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 4.00  | 0.66 | -0.10 | -0.22 | 0.78 | 93.61  | -0.32 | -0.67 | 1.13 | 5.58 | 0.14 | 3.28 | 2.17 |
| 5.00  | 1.00 | -0.22 | -0.25 | 1.03 | 102.31 | -0.67 | -0.78 | 1.13 | 5.58 | 0.14 | 3.28 | 2.17 |
| 6.00  | 1.09 | -0.25 | -0.26 | 1.11 | 104.79 | -0.78 | -0.81 | 1.13 | 5.58 | 0.14 | 3.28 | 2.17 |
| 7.00  | 1.12 | -0.26 | -0.26 | 1.13 | 105.50 | -0.81 | -0.81 | 1.13 | 5.58 | 0.14 | 3.28 | 2.17 |
| 8.00  | 0.91 | -0.26 | -0.14 | 0.79 | 94.20  | -0.81 | -0.46 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 9.00  | 0.57 | -0.14 | -0.12 | 0.54 | 85.55  | -0.46 | -0.36 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 10.00 | 0.48 | -0.12 | -0.10 | 0.47 | 83.09  | -0.36 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 11.00 | 0.50 | -0.10 | -0.13 | 0.52 | 84.94  | -0.33 | -0.40 | 0.59 | 2.93 | 0.03 | 0.73 | 2.17 |
| 12.00 | 0.57 | -0.13 | -0.13 | 0.57 | 86.67  | -0.40 | -0.42 | 0.59 | 2.93 | 0.03 | 0.73 | 2.17 |
| 13.00 | 0.59 | -0.13 | -0.14 | 0.59 | 87.17  | -0.42 | -0.43 | 0.59 | 2.93 | 0.03 | 0.73 | 2.17 |
| 14.00 | 0.59 | -0.14 | -0.14 | 0.59 | 87.31  | -0.43 | -0.43 | 0.59 | 2.93 | 0.03 | 0.73 | 2.17 |
| 15.00 | 0.55 | -0.14 | -0.11 | 0.52 | 84.79  | -0.43 | -0.35 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 16.00 | 0.47 | -0.11 | -0.10 | 0.46 | 82.87  | -0.35 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 17.00 | 0.45 | -0.10 | -0.10 | 0.45 | 82.32  | -0.33 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 18.00 | 0.49 | -0.10 | -0.13 | 0.52 | 84.87  | -0.32 | -0.40 | 0.60 | 2.97 | 0.03 | 0.77 | 2.17 |
| 19.00 | 0.57 | -0.13 | -0.14 | 0.58 | 86.88  | -0.40 | -0.43 | 0.60 | 2.97 | 0.03 | 0.77 | 2.17 |
| 20.00 | 0.59 | -0.14 | -0.14 | 0.60 | 87.45  | -0.43 | -0.43 | 0.60 | 2.97 | 0.03 | 0.77 | 2.17 |
| 21.00 | 0.60 | -0.14 | -0.14 | 0.60 | 87.61  | -0.43 | -0.43 | 0.60 | 2.97 | 0.03 | 0.77 | 2.17 |
| 22.00 | 0.55 | -0.14 | -0.11 | 0.52 | 84.95  | -0.43 | -0.35 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 23.00 | 0.47 | -0.11 | -0.10 | 0.46 | 82.91  | -0.35 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 24.00 | 0.45 | -0.10 | -0.10 | 0.45 | 82.33  | -0.33 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 25.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.16  | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 26.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.12  | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 27.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.10  | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 28.00 | 0.67 | -0.10 | -0.23 | 0.80 | 94.42  | -0.32 | -0.70 | 1.18 | 5.83 | 0.15 | 3.51 | 2.17 |
| 29.00 | 1.05 | -0.23 | -0.26 | 1.08 | 103.79 | -0.70 | -0.81 | 1.19 | 5.84 | 0.15 | 3.52 | 2.17 |
| 30.00 | 1.14 | -0.26 | -0.27 | 1.16 | 106.50 | -0.81 | -0.84 | 1.19 | 5.84 | 0.15 | 3.52 | 2.17 |
| 31.00 | 1.18 | -0.27 | -0.27 | 1.18 | 107.27 | -0.84 | -0.85 | 1.19 | 5.84 | 0.15 | 3.52 | 2.17 |
| 32.00 | 1.18 | -0.27 | -0.27 | 1.18 | 107.49 | -0.85 | -0.85 | 1.19 | 5.84 | 0.15 | 3.52 | 2.17 |
| 33.00 | 0.95 | -0.27 | -0.14 | 0.82 | 95.18  | -0.85 | -0.47 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 34.00 | 0.58 | -0.14 | -0.12 | 0.55 | 85.83  | -0.47 | -0.36 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 35.00 | 0.48 | -0.12 | -0.10 | 0.47 | 83.17  | -0.36 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 36.00 | 0.53 | -0.10 | -0.15 | 0.57 | 86.49  | -0.33 | -0.45 | 0.69 | 3.38 | 0.05 | 1.16 | 2.17 |
| 37.00 | 0.65 | -0.15 | -0.15 | 0.65 | 89.37  | -0.45 | -0.48 | 0.69 | 3.38 | 0.05 | 1.16 | 2.17 |
| 38.00 | 0.67 | -0.15 | -0.16 | 0.68 | 90.19  | -0.48 | -0.49 | 0.69 | 3.38 | 0.05 | 1.16 | 2.17 |
| 39.00 | 0.68 | -0.16 | -0.16 | 0.68 | 90.42  | -0.49 | -0.49 | 0.69 | 3.38 | 0.05 | 1.16 | 2.17 |
| 40.00 | 0.69 | -0.16 | -0.16 | 0.69 | 90.49  | -0.49 | -0.49 | 0.69 | 3.38 | 0.05 | 1.16 | 2.17 |
| 41.00 | 0.61 | -0.16 | -0.12 | 0.57 | 86.42  | -0.49 | -0.37 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 42.00 | 0.49 | -0.12 | -0.11 | 0.48 | 83.33  | -0.37 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 43.00 | 0.46 | -0.11 | -0.10 | 0.45 | 82.45  | -0.33 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 44.00 | 0.59 | -0.10 | -0.18 | 0.67 | 89.86  | -0.32 | -0.56 | 0.90 | 4.44 | 0.09 | 2.18 | 2.17 |
| 45.00 | 0.82 | -0.18 | -0.20 | 0.84 | 95.58  | -0.56 | -0.62 | 0.90 | 4.44 | 0.09 | 2.18 | 2.17 |

|       |      |       |       |      |       |       |       |      |      |      |      |      |
|-------|------|-------|-------|------|-------|-------|-------|------|------|------|------|------|
| 46.00 | 0.88 | -0.20 | -0.21 | 0.88 | 97.22 | -0.62 | -0.64 | 0.90 | 4.44 | 0.09 | 2.18 | 2.17 |
| 47.00 | 0.90 | -0.21 | -0.21 | 0.90 | 97.68 | -0.64 | -0.65 | 0.90 | 4.44 | 0.09 | 2.18 | 2.17 |
| 48.00 | 0.90 | -0.21 | -0.21 | 0.90 | 97.82 | -0.65 | -0.65 | 0.90 | 4.44 | 0.09 | 2.18 | 2.17 |
| 49.00 | 0.76 | -0.21 | -0.13 | 0.68 | 90.19 | -0.65 | -0.41 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 50.00 | 0.53 | -0.13 | -0.11 | 0.51 | 84.41 | -0.41 | -0.34 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 51.00 | 0.47 | -0.11 | -0.10 | 0.46 | 82.76 | -0.34 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 52.00 | 0.45 | -0.10 | -0.10 | 0.45 | 82.29 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 53.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.15 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 54.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.11 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 55.00 | 0.60 | -0.10 | -0.19 | 0.68 | 90.27 | -0.32 | -0.57 | 0.93 | 4.59 | 0.10 | 2.33 | 2.17 |
| 56.00 | 0.84 | -0.19 | -0.20 | 0.86 | 96.45 | -0.57 | -0.64 | 0.93 | 4.59 | 0.10 | 2.33 | 2.17 |
| 57.00 | 0.90 | -0.20 | -0.21 | 0.91 | 98.21 | -0.64 | -0.66 | 0.93 | 4.59 | 0.10 | 2.33 | 2.17 |
| 58.00 | 0.93 | -0.21 | -0.21 | 0.93 | 98.71 | -0.66 | -0.67 | 0.93 | 4.59 | 0.10 | 2.33 | 2.17 |
| 59.00 | 0.93 | -0.21 | -0.21 | 0.93 | 98.86 | -0.67 | -0.67 | 0.93 | 4.59 | 0.10 | 2.33 | 2.17 |
| 60.00 | 0.78 | -0.21 | -0.13 | 0.69 | 90.73 | -0.67 | -0.42 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 61.00 | 0.53 | -0.13 | -0.11 | 0.51 | 84.56 | -0.42 | -0.35 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 62.00 | 0.47 | -0.11 | -0.10 | 0.46 | 82.80 | -0.35 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 63.00 | 0.52 | -0.10 | -0.14 | 0.56 | 86.13 | -0.33 | -0.44 | 0.67 | 3.31 | 0.05 | 1.09 | 2.17 |
| 64.00 | 0.63 | -0.14 | -0.15 | 0.64 | 88.88 | -0.44 | -0.47 | 0.67 | 3.31 | 0.05 | 1.09 | 2.17 |
| 65.00 | 0.66 | -0.15 | -0.15 | 0.66 | 89.67 | -0.47 | -0.48 | 0.67 | 3.31 | 0.05 | 1.09 | 2.17 |
| 66.00 | 0.67 | -0.15 | -0.15 | 0.67 | 89.89 | -0.48 | -0.48 | 0.67 | 3.31 | 0.05 | 1.09 | 2.17 |
| 67.00 | 0.67 | -0.15 | -0.15 | 0.67 | 89.96 | -0.48 | -0.48 | 0.67 | 3.31 | 0.05 | 1.09 | 2.17 |
| 68.00 | 0.60 | -0.15 | -0.11 | 0.56 | 86.15 | -0.48 | -0.36 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 69.00 | 0.48 | -0.11 | -0.11 | 0.47 | 83.25 | -0.36 | -0.33 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 70.00 | 0.45 | -0.11 | -0.10 | 0.45 | 82.43 | -0.33 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 71.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.19 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 72.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.12 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |
| 73.00 | 0.44 | -0.10 | -0.10 | 0.44 | 82.11 | -0.32 | -0.32 | 0.44 | 2.17 | 0.00 | 0.00 | 2.17 |



Subject 3, Task 3, Trial 1, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.8100       | 0.4840       | 4.8457         | 2.3453        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.9000       | 0.3330       | 4.9657         | 1.6536        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.9000       | 0.4600       | 4.9657         | 2.2842        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.7400       | 0.2880       | 4.7524         | 1.3687        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.7200       | 0.3760       | 4.7258         | 1.7769        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.7900       | 0.3300       | 4.8191         | 1.5903        | 0.0000 |
| 3.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 90          | 0.8000       | 0.4420       | 4.8324         | 2.1359        | 0.1204 |
| 4.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 88          | 0.7900       | 0.5410       | 4.8191         | 2.6071        | 0.0562 |
| 4.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 82          | 0.7900       | 0.3950       | 4.8191         | 1.9035        | 0.2754 |
| 5.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 89          | 0.7500       | 0.4390       | 4.7658         | 2.0922        | 0.1347 |
| 5.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 94          | 0.8100       | 0.5270       | 4.8457         | 2.5537        | 0.0599 |
| 6.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 89          | 0.7800       | 0.5340       | 4.8057         | 2.5663        | 0.0590 |
| 6.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 90          | 0.7800       | 0.3760       | 4.8057         | 1.8070        | 0.5920 |
| 7.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 91          | 0.7600       | 0.5280       | 4.7791         | 2.5234        | 0.0621 |
| 7.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 90          | 0.7900       | 0.5340       | 4.8191         | 2.5734        | 0.0585 |
| 8.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 91          | 0.8100       | 0.4430       | 4.8457         | 2.1467        | 0.1174 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.7800       | 0.7170       | 4.8057         | 3.4457        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 93          | 0.7400       | 0.4000       | 4.7524         | 1.9010        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.7700       | 0.3880       | 4.7924         | 1.8595        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.7900       | 0.3740       | 4.8191         | 1.8023        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.7900       | 0.2550       | 4.8191         | 1.2289        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8900       | 0.3200       | 4.9524         | 1.5848        | 0.0000 |
| 11.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 82          | 0.8600       | 0.4230       | 4.9124         | 2.0779        | 0.0887 |
| 12.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 80          | 0.9100       | 0.4530       | 4.9790         | 2.2555        | 0.0600 |
| 12.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 89          | 0.8300       | 0.3980       | 4.8724         | 1.9392        | 0.1414 |
| 13.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 91          | 0.8100       | 0.4590       | 4.8457         | 2.2242        | 0.0636 |
| 13.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 91          | 0.8700       | 0.6310       | 4.9257         | 3.1081        | 0.0235 |
| 14.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 88          | 0.7900       | 0.4010       | 4.8191         | 1.9324        | 0.1457 |
| 14.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 87          | 0.7700       | 0.5380       | 4.7924         | 2.5783        | 0.0378 |
| 15.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 91          | 0.7900       | 0.5660       | 4.8191         | 2.7276        | 0.0323 |
| 15.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 87          | 0.7900       | 0.4330       | 4.8191         | 2.0867        | 0.0866 |
| 16.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 87          | 0.7900       | 0.5630       | 4.8191         | 2.7131        | 0.0327 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.8100       | 0.8000       | 4.8457         | 3.8766        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.7500       | 0.3670       | 4.7658         | 1.7490        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.7400       | 0.3630       | 4.7524         | 1.7251        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.7300       | 0.3310       | 4.7391         | 1.5686        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.8000       | 0.4600       | 4.8324         | 2.2229        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.8200       | 0.2330       | 4.8591         | 1.1322        | 0.0000 |
| 19.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 90          | 0.8900       | 0.5300       | 4.9524         | 2.6248        | 0.1085 |
| 20.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.7900       | 0.5320       | 4.8191         | 2.5637        | 0.1168 |
| 20.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.7500       | 0.7770       | 4.7658         | 3.7030        | 0.0481 |
| 21.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.7400       | 0.8400       | 4.7524         | 3.9920        | 0.0419 |
| 21.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 109         | 0.7400       | 1.0040       | 4.7524         | 4.7714        | 0.0310 |
| 22.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.7600       | 0.8510       | 4.7791         | 4.0670        | 0.0405 |
| 22.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 103         | 0.7600       | 0.8640       | 4.7791         | 4.1291        | 0.0394 |
| 23.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 103         | 0.7500       | 0.8610       | 4.7658         | 4.1033        | 0.0399 |

|      |   |    |       |        |        |     |        |        |        |        |        |
|------|---|----|-------|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 4 | 15 | Squat | 6.5000 | 0.0931 | 106 | 0.7600 | 0.8610 | 4.7791 | 4.1148 | 0.0397 |
| 24.0 | 4 | 15 | Squat | 6.5000 | 0.0931 | 103 | 0.7700 | 0.8250 | 4.7924 | 3.9537 | 0.0426 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 84  | 0.8000 | 0.8840 | 4.8324 | 4.2718 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 86  | 0.7800 | 0.4410 | 4.8057 | 2.1193 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 85  | 0.7800 | 0.4740 | 4.8057 | 2.2779 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 85  | 0.8000 | 0.3070 | 4.8324 | 1.4835 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 85  | 0.8600 | 0.3420 | 4.9124 | 1.6800 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 88  | 0.8100 | 0.3080 | 4.8457 | 1.4925 | 0.0000 |

Subject 3, Task 3, Trial 2, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.7600       | 0.3830       | 4.7791         | 1.8304        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 73          | 0.7900       | 0.4220       | 4.8191         | 2.0336        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.7800       | 0.2450       | 4.8057         | 1.1774        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.8000       | 0.3300       | 4.8324         | 1.5947        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 71          | 0.9000       | 0.4000       | 4.9657         | 1.9863        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 89          | 0.8200       | 0.3090       | 4.8591         | 1.5014        | 0.0000 |
| 3.5         | 6                | 5          | Squat | 3.2500        | 0.0466           | 83          | 0.8300       | 0.4240       | 4.8724         | 2.0659        | 0.1413 |
| 4.0         | 6                | 5          | Squat | 3.2500        | 0.0466           | 87          | 0.8000       | 0.5530       | 4.8324         | 2.6723        | 0.0498 |
| 4.5         | 6                | 5          | Squat | 3.2500        | 0.0466           | 87          | 0.8600       | 0.5600       | 4.9124         | 2.7509        | 0.0459 |
| 5.0         | 6                | 5          | Squat | 3.2500        | 0.0466           | 97          | 0.7700       | 0.7320       | 4.7924         | 3.5080        | 0.0263 |
| 5.5         | 6                | 5          | Squat | 3.2500        | 0.0466           | 101         | 0.7800       | 0.7020       | 4.8057         | 3.3736        | 0.0284 |
| 6.0         | 6                | 5          | Squat | 3.2500        | 0.0466           | 93          | 0.7700       | 0.7740       | 4.7924         | 3.7093        | 0.0236 |
| 6.5         | 6                | 5          | Squat | 3.2500        | 0.0466           | 92          | 0.7800       | 0.7110       | 4.8057         | 3.4169        | 0.0277 |
| 7.0         | 6                | 5          | Squat | 3.2500        | 0.0466           | 94          | 0.7800       | 0.9100       | 4.8057         | 4.3732        | 0.0177 |
| 7.5         | 6                | 5          | Squat | 3.2500        | 0.0466           | 93          | 0.7800       | 0.6080       | 4.8057         | 2.9219        | 0.0393 |
| 8.0         | 6                | 5          | Squat | 3.2500        | 0.0466           | 92          | 0.7700       | 0.8230       | 4.7924         | 3.9442        | 0.0211 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.7500       | 0.9590       | 4.7658         | 4.5704        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8200       | 0.4300       | 4.8591         | 2.0894        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.8200       | 0.4010       | 4.8591         | 1.9485        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 70          | 0.9200       | 0.4650       | 4.9924         | 2.3214        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.7900       | 0.4530       | 4.8191         | 2.1830        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8700       | 0.3080       | 4.9257         | 1.5171        | 0.0000 |
| 11.5        | 4                | 15         | Arm   | 0.0000        | 0.0000           | 84          | 0.9100       | 0.4730       | 4.9790         | 2.3551        | 0.0000 |
| 12.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 78          | 0.8700       | 0.4160       | 4.9257         | 2.0491        | 0.3817 |
| 12.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 99          | 0.8500       | 0.4730       | 4.8991         | 2.3173        | 0.1880 |
| 13.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 83          | 0.8500       | 0.6080       | 4.8991         | 2.9786        | 0.0835 |
| 13.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 88          | 0.8300       | 0.8820       | 4.8724         | 4.2974        | 0.0396 |
| 14.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 85          | 0.8400       | 0.9490       | 4.8857         | 4.6365        | 0.0349 |
| 14.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 96          | 0.8600       | 0.7770       | 4.9124         | 3.8169        | 0.0490 |
| 15.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 94          | 0.8200       | 0.8310       | 4.8591         | 4.0379        | 0.0442 |
| 15.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 89          | 0.8100       | 0.4760       | 4.8457         | 2.3066        | 0.1919 |
| 16.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 87          | 0.8600       | 0.8400       | 4.9124         | 4.1264        | 0.0425 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.8500       | 0.4450       | 4.8991         | 2.1801        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8500       | 0.6460       | 4.8991         | 3.1648        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.9100       | 0.4150       | 4.9790         | 2.0663        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 72          | 0.8400       | 0.2560       | 4.8857         | 1.2507        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 74          | 0.9000       | 0.3300       | 4.9657         | 1.6387        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 70          | 0.8800       | 0.2650       | 4.9390         | 1.3088        | 0.0000 |
| 19.5        | 6                | 15         | Arm   | 0.0000        | 0.0000           | 86          | 0.8800       | 0.5370       | 4.9390         | 2.6523        | 0.0000 |
| 20.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 92          | 0.8700       | 0.4450       | 4.9257         | 2.1919        | 0.4219 |
| 20.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 92          | 0.8500       | 0.6710       | 4.8991         | 3.2873        | 0.1029 |
| 21.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 95          | 0.8300       | 0.7510       | 4.8724         | 3.6592        | 0.0819 |
| 21.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 93          | 0.8100       | 0.7440       | 4.8457         | 3.6052        | 0.0844 |
| 22.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 94          | 0.8500       | 0.8340       | 4.8991         | 4.0858        | 0.0663 |
| 22.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 89          | 0.8600       | 0.7460       | 4.9124         | 3.6646        | 0.0816 |
| 23.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 100         | 0.8500       | 0.9220       | 4.8991         | 4.5169        | 0.0556 |

|      |   |    |     |         |        |    |        |        |        |        |        |
|------|---|----|-----|---------|--------|----|--------|--------|--------|--------|--------|
| 23.5 | 6 | 15 | Arm | 10.4000 | 0.1490 | 90 | 0.8700 | 0.8620 | 4.9257 | 4.2460 | 0.0619 |
| 24.0 | 6 | 15 | Arm | 10.4000 | 0.1490 | 92 | 0.8800 | 0.7770 | 4.9390 | 3.8376 | 0.0746 |
| 24.5 |   |    | Sit | 0.0000  | 0.0000 | 80 | 0.8600 | 0.7450 | 4.9124 | 3.6597 | 0.0000 |
| 25.0 |   |    | Sit | 0.0000  | 0.0000 | 82 | 0.8600 | 0.5990 | 4.9124 | 2.9425 | 0.0000 |
| 25.5 |   |    | Sit | 0.0000  | 0.0000 | 83 | 0.8900 | 0.2810 | 4.9524 | 1.3916 | 0.0000 |
| 26.0 |   |    | Sit | 0.0000  | 0.0000 | 78 | 0.8900 | 0.3800 | 4.9524 | 1.8819 | 0.0000 |
| 26.5 |   |    | Sit | 0.0000  | 0.0000 | 72 | 0.8600 | 0.2820 | 4.9124 | 1.3853 | 0.0000 |
| 27.0 |   |    | Sit | 0.0000  | 0.0000 | 74 | 0.8500 | 0.2600 | 4.8991 | 1.2738 | 0.0000 |



Subject 3, Task 3, Trial 3, experimentally collected data

| Time<br>min<br>**** | Freq.<br>Lif/min<br>**** | Load<br>Kg<br>**** | Type<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>**** | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|---------------------|--------------------------|--------------------|--------------|-----------------------|------------------|---------------------|----------------------|-------------|----------------|---------------|--------|
| 0.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 64                  | 0.7200               | 0.7480      | 4.7258         | 3.5349        | 0.0000 |
| 1.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 67                  | 0.7300               | 0.6190      | 4.7391         | 2.9335        | 0.0000 |
| 1.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 68                  | 0.7100               | 0.3110      | 4.7124         | 1.4656        | 0.0000 |
| 2.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 71                  | 0.7200               | 0.2040      | 4.7258         | 0.9641        | 0.0000 |
| 2.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 75                  | 0.7100               | 0.2600      | 4.7124         | 1.2252        | 0.0000 |
| 3.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 65                  | 0.7200               | 0.2580      | 4.7258         | 1.2192        | 0.0000 |
| 3.5                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 82                  | 0.7900               | 0.4090      | 4.8191         | 1.9710        | 0.3058 |
| 4.0                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 101                 | 0.7200               | 0.6720      | 4.7258         | 3.1757        | 0.0841 |
| 4.5                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 103                 | 0.6700               | 0.9270      | 4.6591         | 4.3190        | 0.0499 |
| 5.0                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 103                 | 0.6600               | 1.1370      | 4.6458         | 5.2823        | 0.0371 |
| 5.5                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 103                 | 0.6400               | 1.2480      | 4.6191         | 5.7647        | 0.0329 |
| 6.0                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 112                 | 0.6600               | 1.0920      | 4.6458         | 5.0732        | 0.0393 |
| 6.5                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 97                  | 0.6700               | 1.1150      | 4.6591         | 5.1949        | 0.0380 |
| 7.0                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 99                  | 0.6800               | 1.1280      | 4.6724         | 5.2705        | 0.0372 |
| 7.5                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 105                 | 0.7100               | 1.1400      | 4.7124         | 5.3722        | 0.0362 |
| 8.0                 | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 103                 | 0.7100               | 1.0530      | 4.7124         | 4.9622        | 0.0406 |
| 8.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 96                  | 0.7200               | 1.1150      | 4.7258         | 5.2692        | 0.0000 |
| 9.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 74                  | 0.7300               | 0.5590      | 4.7391         | 2.6492        | 0.0000 |
| 9.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 75                  | 0.7800               | 0.3960      | 4.8057         | 1.9031        | 0.0000 |
| 10.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.7800               | 0.4330      | 4.8057         | 2.0809        | 0.0000 |
| 10.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 80                  | 0.7700               | 0.2920      | 4.7924         | 1.3994        | 0.0000 |
| 11.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 75                  | 0.7900               | 0.2070      | 4.8191         | 0.9975        | 0.0000 |
| 11.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 80                  | 0.8700               | 0.5090      | 4.9257         | 2.5072        | 0.0282 |
| 12.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 89                  | 0.8300               | 0.5600      | 4.8724         | 2.7285        | 0.0235 |
| 12.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 92                  | 0.8400               | 0.5640      | 4.8857         | 2.7555        | 0.0230 |
| 13.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 91                  | 0.7800               | 0.6000      | 4.8057         | 2.8834        | 0.0210 |
| 13.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 90                  | 0.7700               | 0.6780      | 4.7924         | 3.2493        | 0.0169 |
| 14.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 91                  | 0.7800               | 0.6140      | 4.8057         | 2.9507        | 0.0201 |
| 14.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 90                  | 0.7500               | 0.5970      | 4.7658         | 2.8452        | 0.0216 |
| 15.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 93                  | 0.7400               | 0.6000      | 4.7524         | 2.8515        | 0.0215 |
| 15.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 91                  | 0.7500               | 0.6220      | 4.7658         | 2.9643        | 0.0199 |
| 16.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 86                  | 0.7400               | 0.7130      | 4.7524         | 3.3885        | 0.0157 |
| 16.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 85                  | 0.7300               | 0.5900      | 4.7391         | 2.7961        | 0.0000 |
| 17.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 80                  | 0.7800               | 0.5020      | 4.8057         | 2.4125        | 0.0000 |
| 17.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.7200               | 0.5100      | 4.7258         | 2.4101        | 0.0000 |
| 18.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 73                  | 0.7200               | 0.2900      | 4.7258         | 1.3705        | 0.0000 |
| 18.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.7000               | 0.1080      | 4.6991         | 0.5075        | 0.0000 |
| 19.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 70                  | 0.7200               | 0.1320      | 4.7258         | 0.6238        | 0.0000 |



## Subject 3, Test 3

| Equation Type      | Equation                                    | Equation Parameters |        |       |         |
|--------------------|---------------------------------------------|---------------------|--------|-------|---------|
| regression<br>i/t  | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.23   | alfa= | 0.58    |
| balance            | $X1 + X2 = X3 + X4$                         |                     |        |       |         |
| regression<br>gain | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.72   | alfa= | 0.32    |
| i/t                | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0305 | C =   | -1.9627 |
| balance            | $X4 + X6 = X7 + X8$                         |                     |        |       |         |
| gain               | $X9 = Y * X8$                               | Y =                 | 4.8262 |       |         |
| balance            | $X9 = X10 + X11 + X12$                      |                     |        |       |         |
| exogenous          |                                             |                     |        |       |         |
| regression         | $X10 = \text{Eff} * X11$                    | Eff =               | 0.0442 |       |         |
| exogenous          | $X12 = \text{RM}$                           | RM =                | 1.5835 |       |         |

|   |        |        |    |      |        |        |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|------|--------|--------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0    | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0    | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.109  | i/t |
| 1 | 1      | -1     | -1 | 0    | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0    | 0.4444 | 0.9444 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.03 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 1.96274 | i/t |
| 0 | 0      | 0      | 0  | 0    | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.2516 |     |
| 0 | 0      | 0      | 1  | 0    | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0    | 0      | 0      | 4.826 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0    | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0    | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0    | 0      | 0      | 0     | 0  | -1 | 0.044 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0    | 0      | 0      | 0     | 0  | 0  | 0     | 1 | 1 | X12 | = | 1.5835  |     |

Subject 3, Task 3, model solution

| Time  | X1   | X2    | X3    | X4   | X5    | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|-------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00  | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.39 | -0.11 | -0.06 | 0.34 | 75.49 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 1.00  | 0.31 | -0.06 | -0.08 | 0.33 | 75.23 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 2.00  | 0.34 | -0.08 | -0.07 | 0.33 | 75.16 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 3.00  | 0.32 | -0.07 | -0.08 | 0.33 | 75.14 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 4.00  | 0.41 | -0.08 | -0.12 | 0.45 | 79.01 | -0.24 | -0.36 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 5.00  | 0.52 | -0.12 | -0.13 | 0.54 | 81.93 | -0.36 | -0.40 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 6.00  | 0.56 | -0.13 | -0.13 | 0.56 | 82.77 | -0.40 | -0.41 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 7.00  | 0.57 | -0.13 | -0.13 | 0.57 | 83.01 | -0.41 | -0.41 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 8.00  | 0.57 | -0.13 | -0.13 | 0.57 | 83.08 | -0.41 | -0.41 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 9.00  | 0.49 | -0.13 | -0.09 | 0.45 | 79.22 | -0.41 | -0.29 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 10.00 | 0.37 | -0.09 | -0.08 | 0.36 | 76.30 | -0.29 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 11.00 | 0.34 | -0.08 | -0.08 | 0.34 | 75.46 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 12.00 | 0.38 | -0.08 | -0.10 | 0.41 | 77.79 | -0.24 | -0.32 | 0.49 | 2.36 | 0.03 | 0.75 | 1.58 |
| 13.00 | 0.46 | -0.10 | -0.11 | 0.47 | 79.67 | -0.32 | -0.34 | 0.49 | 2.36 | 0.03 | 0.75 | 1.58 |
| 14.00 | 0.48 | -0.11 | -0.11 | 0.48 | 80.20 | -0.34 | -0.35 | 0.49 | 2.36 | 0.03 | 0.75 | 1.58 |
| 15.00 | 0.49 | -0.11 | -0.11 | 0.49 | 80.36 | -0.35 | -0.35 | 0.49 | 2.36 | 0.03 | 0.75 | 1.58 |
| 16.00 | 0.49 | -0.11 | -0.11 | 0.49 | 80.40 | -0.35 | -0.35 | 0.49 | 2.36 | 0.03 | 0.75 | 1.58 |
| 17.00 | 0.44 | -0.11 | -0.08 | 0.41 | 77.84 | -0.35 | -0.27 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 18.00 | 0.36 | -0.08 | -0.08 | 0.35 | 75.90 | -0.27 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 19.00 | 0.34 | -0.08 | -0.08 | 0.33 | 75.35 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 20.00 | 0.47 | -0.08 | -0.15 | 0.55 | 82.45 | -0.24 | -0.47 | 0.78 | 3.78 | 0.09 | 2.11 | 1.58 |
| 21.00 | 0.70 | -0.15 | -0.17 | 0.72 | 87.89 | -0.47 | -0.54 | 0.78 | 3.78 | 0.09 | 2.11 | 1.58 |
| 22.00 | 0.76 | -0.17 | -0.18 | 0.76 | 89.45 | -0.54 | -0.56 | 0.78 | 3.78 | 0.09 | 2.11 | 1.58 |
| 23.00 | 0.78 | -0.18 | -0.18 | 0.78 | 89.89 | -0.56 | -0.56 | 0.78 | 3.78 | 0.09 | 2.11 | 1.58 |
| 24.00 | 0.78 | -0.18 | -0.18 | 0.78 | 90.02 | -0.56 | -0.56 | 0.78 | 3.78 | 0.09 | 2.11 | 1.58 |
| 25.00 | 0.64 | -0.18 | -0.10 | 0.56 | 82.80 | -0.56 | -0.33 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 26.00 | 0.41 | -0.10 | -0.08 | 0.39 | 77.32 | -0.33 | -0.26 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 27.00 | 0.36 | -0.08 | -0.08 | 0.35 | 75.76 | -0.26 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 28.00 | 0.33 | -0.08 | -0.08 | 0.33 | 75.31 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 29.00 | 0.33 | -0.08 | -0.08 | 0.33 | 75.18 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 30.00 | 0.33 | -0.08 | -0.08 | 0.33 | 75.14 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 31.00 | 0.40 | -0.08 | -0.11 | 0.44 | 78.76 | -0.24 | -0.35 | 0.56 | 2.68 | 0.05 | 1.05 | 1.58 |
| 32.00 | 0.51 | -0.11 | -0.12 | 0.52 | 81.50 | -0.35 | -0.39 | 0.56 | 2.68 | 0.05 | 1.05 | 1.58 |
| 33.00 | 0.54 | -0.12 | -0.13 | 0.55 | 82.29 | -0.39 | -0.40 | 0.56 | 2.68 | 0.05 | 1.05 | 1.58 |
| 34.00 | 0.55 | -0.13 | -0.13 | 0.55 | 82.51 | -0.40 | -0.40 | 0.56 | 2.68 | 0.05 | 1.05 | 1.58 |
| 35.00 | 0.55 | -0.13 | -0.13 | 0.56 | 82.57 | -0.40 | -0.40 | 0.56 | 2.68 | 0.05 | 1.05 | 1.58 |
| 36.00 | 0.48 | -0.13 | -0.09 | 0.45 | 78.96 | -0.40 | -0.28 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 37.00 | 0.37 | -0.09 | -0.08 | 0.36 | 76.23 | -0.28 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 38.00 | 0.34 | -0.08 | -0.08 | 0.34 | 75.44 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 39.00 | 0.41 | -0.08 | -0.12 | 0.45 | 79.09 | -0.24 | -0.36 | 0.57 | 2.76 | 0.05 | 1.12 | 1.58 |
| 40.00 | 0.60 | -0.12 | -0.17 | 0.65 | 85.82 | -0.36 | -0.52 | 0.81 | 3.93 | 0.10 | 2.24 | 1.58 |
| 41.00 | 0.75 | -0.17 | -0.18 | 0.77 | 89.56 | -0.52 | -0.57 | 0.81 | 3.93 | 0.10 | 2.24 | 1.58 |
| 42.00 | 0.80 | -0.18 | -0.19 | 0.80 | 90.63 | -0.57 | -0.58 | 0.81 | 3.93 | 0.10 | 2.24 | 1.58 |
| 43.00 | 0.81 | -0.19 | -0.19 | 0.81 | 90.94 | -0.58 | -0.58 | 0.81 | 3.93 | 0.10 | 2.24 | 1.58 |
| 44.00 | 0.66 | -0.19 | -0.10 | 0.58 | 83.29 | -0.58 | -0.34 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 45.00 | 0.42 | -0.10 | -0.09 | 0.40 | 77.46 | -0.34 | -0.26 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |

|       |      |       |       |      |       |       |       |      |      |      |      |      |
|-------|------|-------|-------|------|-------|-------|-------|------|------|------|------|------|
| 46.00 | 0.36 | -0.09 | -0.08 | 0.35 | 75.80 | -0.26 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 47.00 | 0.45 | -0.08 | -0.14 | 0.51 | 81.13 | -0.24 | -0.43 | 0.69 | 3.34 | 0.07 | 1.68 | 1.58 |
| 48.00 | 0.74 | -0.14 | -0.21 | 0.82 | 91.19 | -0.43 | -0.67 | 1.06 | 5.10 | 0.15 | 3.37 | 1.58 |
| 49.00 | 0.97 | -0.21 | -0.23 | 0.99 | 96.79 | -0.67 | -0.73 | 1.06 | 5.10 | 0.15 | 3.37 | 1.58 |
| 50.00 | 1.03 | -0.23 | -0.24 | 1.04 | 98.39 | -0.73 | -0.75 | 1.06 | 5.10 | 0.15 | 3.37 | 1.58 |
| 51.00 | 1.05 | -0.24 | -0.24 | 1.05 | 98.85 | -0.75 | -0.76 | 1.06 | 5.10 | 0.15 | 3.37 | 1.58 |
| 52.00 | 0.83 | -0.24 | -0.12 | 0.70 | 87.37 | -0.76 | -0.39 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 53.00 | 0.46 | -0.12 | -0.09 | 0.43 | 78.63 | -0.39 | -0.28 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 54.00 | 0.37 | -0.09 | -0.08 | 0.36 | 76.13 | -0.28 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 55.00 | 0.34 | -0.08 | -0.08 | 0.34 | 75.41 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 56.00 | 0.33 | -0.08 | -0.08 | 0.33 | 75.21 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 57.00 | 0.33 | -0.08 | -0.08 | 0.33 | 75.15 | -0.24 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 58.00 | 0.54 | -0.08 | -0.19 | 0.66 | 86.03 | -0.24 | -0.59 | 1.01 | 4.88 | 0.14 | 3.16 | 1.58 |
| 59.00 | 0.89 | -0.19 | -0.22 | 0.91 | 94.27 | -0.59 | -0.69 | 1.01 | 4.88 | 0.14 | 3.16 | 1.58 |
| 60.00 | 0.97 | -0.22 | -0.23 | 0.98 | 96.62 | -0.69 | -0.72 | 1.01 | 4.88 | 0.14 | 3.16 | 1.58 |
| 61.00 | 1.00 | -0.23 | -0.23 | 1.00 | 97.30 | -0.72 | -0.73 | 1.01 | 4.88 | 0.14 | 3.16 | 1.58 |
| 62.00 | 1.01 | -0.23 | -0.23 | 1.01 | 97.49 | -0.73 | -0.73 | 1.01 | 4.88 | 0.14 | 3.16 | 1.58 |
| 63.00 | 0.80 | -0.23 | -0.11 | 0.68 | 86.65 | -0.73 | -0.38 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 64.00 | 0.45 | -0.11 | -0.09 | 0.43 | 78.42 | -0.38 | -0.28 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 65.00 | 0.37 | -0.09 | -0.08 | 0.36 | 76.07 | -0.28 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 66.00 | 0.38 | -0.08 | -0.10 | 0.41 | 77.82 | -0.25 | -0.32 | 0.48 | 2.32 | 0.03 | 0.70 | 1.58 |
| 67.00 | 0.46 | -0.10 | -0.11 | 0.46 | 79.46 | -0.32 | -0.34 | 0.48 | 2.32 | 0.03 | 0.70 | 1.58 |
| 68.00 | 0.47 | -0.11 | -0.11 | 0.47 | 79.93 | -0.34 | -0.34 | 0.48 | 2.32 | 0.03 | 0.70 | 1.58 |
| 69.00 | 0.48 | -0.11 | -0.11 | 0.48 | 80.06 | -0.34 | -0.35 | 0.48 | 2.32 | 0.03 | 0.70 | 1.58 |
| 70.00 | 0.48 | -0.11 | -0.11 | 0.48 | 80.10 | -0.35 | -0.35 | 0.48 | 2.32 | 0.03 | 0.70 | 1.58 |
| 71.00 | 0.43 | -0.11 | -0.08 | 0.41 | 77.69 | -0.35 | -0.27 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 72.00 | 0.36 | -0.08 | -0.08 | 0.35 | 75.86 | -0.27 | -0.25 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |
| 73.00 | 0.34 | -0.08 | -0.08 | 0.33 | 75.34 | -0.25 | -0.24 | 0.33 | 1.58 | 0.00 | 0.00 | 1.58 |



Subject 4, Task 3, Trial 1, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 90          | 0.8200       | 0.3410       | 4.8591         | 1.6569        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 91          | 0.9000       | 0.4920       | 4.9657         | 2.4431        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 96          | 0.8700       | 0.2790       | 4.9257         | 1.3743        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 95          | 0.8800       | 0.5390       | 4.9390         | 2.6621        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 98          | 1.0000       | 0.3720       | 5.0990         | 1.8968        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 93          | 0.9000       | 0.3800       | 4.9657         | 1.8870        | 0.0000 |
| 3.5         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 94          | 0.8300       | 0.5950       | 4.8724         | 2.8991        | 0.0470 |
| 4.0         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 105         | 0.8800       | 0.5640       | 4.9390         | 2.7856        | 0.0561 |
| 4.5         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 95          | 0.8600       | 0.6100       | 4.9124         | 2.9966        | 0.0413 |
| 5.0         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 92          | 0.8600       | 0.6360       | 4.9124         | 3.1243        | 0.0356 |
| 5.5         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 96          | 0.8600       | 0.6460       | 4.9124         | 3.1734        | 0.0338 |
| 6.0         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 103         | 0.8200       | 0.7210       | 4.8591         | 3.5034        | 0.0252 |
| 6.5         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 94          | 0.8700       | 0.6880       | 4.9257         | 3.3889        | 0.0277 |
| 7.0         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 96          | 0.8600       | 0.6740       | 4.9124         | 3.3109        | 0.0296 |
| 7.5         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 102         | 0.8600       | 0.6410       | 4.9124         | 3.1488        | 0.0347 |
| 8.0         | 4                | 5          | Arm   | 2.3000        | 0.0330           | 98          | 0.8300       | 0.5690       | 4.8724         | 2.7724        | 0.0574 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 97          | 0.8200       | 0.9120       | 4.8591         | 4.4315        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 95          | 0.9000       | 0.5810       | 4.9657         | 2.8851        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 102         | 0.9700       | 0.4780       | 5.0590         | 2.4182        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 97          | 0.9300       | 0.3970       | 5.0057         | 1.9873        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 93          | 0.8500       | 0.3960       | 4.8991         | 1.9400        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 95          | 0.8700       | 0.3600       | 4.9257         | 1.7733        | 0.0000 |
| 11.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 100         | 0.7900       | 0.5450       | 4.8191         | 2.6264        | 0.0722 |
| 12.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 101         | 0.8300       | 0.7090       | 4.8724         | 3.4545        | 0.0247 |
| 12.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 108         | 0.8400       | 0.8730       | 4.8857         | 4.2652        | 0.0150 |
| 13.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 105         | 0.8300       | 0.8750       | 4.8724         | 4.2633        | 0.0150 |
| 13.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 104         | 0.8300       | 0.9450       | 4.8724         | 4.6044        | 0.0129 |
| 14.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 107         | 0.8700       | 0.7820       | 4.9257         | 3.8519        | 0.0188 |
| 14.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 100         | 0.8400       | 0.8390       | 4.8857         | 4.0991        | 0.0163 |
| 15.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 99          | 0.8300       | 0.8560       | 4.8724         | 4.1708        | 0.0157 |
| 15.5        | 4                | 5          | Squat | 2.1700        | 0.0311           | 106         | 0.8500       | 0.8150       | 4.8991         | 3.9927        | 0.0173 |
| 16.0        | 4                | 5          | Squat | 2.1700        | 0.0311           | 105         | 0.8600       | 0.8190       | 4.9124         | 4.0232        | 0.0170 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 101         | 0.8000       | 0.9530       | 4.8324         | 4.6053        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 90          | 0.9100       | 0.7010       | 4.9790         | 3.4903        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.9400       | 0.5120       | 5.0190         | 2.5697        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 104         | 1.0200       | 0.4440       | 5.1257         | 2.2758        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 98          | 1.0000       | 0.2900       | 5.0990         | 1.4787        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 97          | 0.8500       | 0.3830       | 4.8991         | 1.8763        | 0.0000 |
| 19.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 107         | 0.8400       | 0.5940       | 4.8857         | 2.9021        | 0.0674 |
| 20.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 113         | 0.8800       | 0.7370       | 4.9390         | 3.6401        | 0.0326 |
| 20.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 110         | 0.8100       | 0.9990       | 4.8457         | 4.8409        | 0.0177 |
| 21.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 115         | 0.8200       | 1.0010       | 4.8591         | 4.8639        | 0.0176 |
| 21.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 102         | 0.8500       | 0.9950       | 4.8991         | 4.8746        | 0.0175 |
| 22.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 108         | 0.8400       | 1.0130       | 4.8857         | 4.9492        | 0.0170 |
| 22.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 110         | 0.8500       | 0.9760       | 4.8991         | 4.7815        | 0.0181 |
| 23.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 109         | 0.8500       | 1.0130       | 4.8991         | 4.9627        | 0.0169 |

|      |   |   |       |        |        |     |        |        |        |        |        |
|------|---|---|-------|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 6 | 5 | Squat | 3.2500 | 0.0466 | 113 | 0.8500 | 1.0090 | 4.8991 | 4.9431 | 0.0170 |
| 24.0 | 6 | 5 | Squat | 3.2500 | 0.0466 | 118 | 0.8400 | 1.0730 | 4.8857 | 5.2424 | 0.0154 |
| 24.5 |   |   | Sit   | 0.0000 | 0.0000 | 113 | 0.8600 | 1.1190 | 4.9124 | 5.4970 | 0.0000 |
| 25.0 |   |   | Sit   | 0.0000 | 0.0000 | 107 | 0.8900 | 0.6980 | 4.9524 | 3.4568 | 0.0000 |
| 25.5 |   |   | Sit   | 0.0000 | 0.0000 | 104 | 0.9300 | 0.6230 | 5.0057 | 3.1185 | 0.0000 |
| 26.0 |   |   | Sit   | 0.0000 | 0.0000 | 109 | 1.0000 | 0.5370 | 5.0990 | 2.7382 | 0.0000 |
| 26.5 |   |   | Sit   | 0.0000 | 0.0000 | 106 | 0.9200 | 0.4740 | 4.9924 | 2.3664 | 0.0000 |
| 27.0 |   |   | Sit   | 0.0000 | 0.0000 | 102 | 0.9100 | 0.4570 | 4.9790 | 2.2754 | 0.0000 |

Subject 4, Task 3, Trial 2, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8500       | 0.2640       | 4.8991         | 1.2933        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.9100       | 0.3200       | 4.9790         | 1.5933        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8300       | 0.3290       | 4.8724         | 1.6030        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.8700       | 0.3010       | 4.9257         | 1.4826        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.8800       | 0.3290       | 4.9390         | 1.6249        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8600       | 0.3360       | 4.9124         | 1.6506        | 0.0000 |
| 3.5         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 96          | 0.8800       | 0.6000       | 4.9390         | 2.9634        | 0.2037 |
| 4.0         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 95          | 0.8400       | 0.7660       | 4.8857         | 3.7425        | 0.0987 |
| 4.5         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 100         | 0.8500       | 0.8970       | 4.8991         | 4.3944        | 0.0689 |
| 5.0         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 101         | 0.8500       | 0.9690       | 4.8991         | 4.7472        | 0.0592 |
| 5.5         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 91          | 0.8400       | 0.9080       | 4.8857         | 4.4362        | 0.0676 |
| 6.0         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 100         | 0.8600       | 0.9620       | 4.9124         | 4.7257        | 0.0598 |
| 6.5         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 102         | 0.8500       | 1.0550       | 4.8991         | 5.1685        | 0.0507 |
| 7.0         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 106         | 0.8600       | 0.9710       | 4.9124         | 4.7699        | 0.0587 |
| 7.5         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 103         | 0.8600       | 1.0880       | 4.9124         | 5.3447        | 0.0479 |
| 8.0         | 6                | 15         | Arm   | 10.4000       | 0.1490           | 106         | 0.8800       | 0.9580       | 4.9390         | 4.7316        | 0.0596 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.8700       | 1.0410       | 4.9257         | 5.1277        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.9300       | 0.6270       | 5.0057         | 3.1386        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 89          | 0.9200       | 0.4660       | 4.9924         | 2.3264        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.9200       | 0.3840       | 4.9924         | 1.9171        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.9300       | 0.3720       | 5.0057         | 1.8621        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.9000       | 0.3090       | 4.9657         | 1.5344        | 0.0000 |
| 11.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 93          | 0.8400       | 0.7470       | 4.8857         | 3.6496        | 0.0677 |
| 12.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 99          | 0.9100       | 0.7760       | 4.9790         | 3.8637        | 0.0591 |
| 12.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 97          | 0.8800       | 0.7700       | 4.9390         | 3.8031        | 0.0613 |
| 13.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 97          | 0.8700       | 0.8490       | 4.9257         | 4.1819        | 0.0497 |
| 13.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 104         | 0.8600       | 0.8300       | 4.9124         | 4.0773        | 0.0524 |
| 14.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 100         | 0.8500       | 0.8040       | 4.8991         | 3.9388        | 0.0565 |
| 14.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 101         | 0.8700       | 0.8300       | 4.9257         | 4.0883        | 0.0521 |
| 15.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 95          | 0.8700       | 0.8310       | 4.9257         | 4.0933        | 0.0520 |
| 15.5        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 100         | 0.8900       | 0.8230       | 4.9524         | 4.0758        | 0.0524 |
| 16.0        | 4                | 15         | Arm   | 6.9300        | 0.0993           | 100         | 0.8700       | 0.7540       | 4.9257         | 3.7140        | 0.0648 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 90          | 0.8500       | 0.9990       | 4.8991         | 4.8942        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.9300       | 0.5890       | 5.0057         | 2.9484        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 89          | 0.9100       | 0.5980       | 4.9790         | 2.9775        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.9400       | 0.4420       | 5.0190         | 2.2184        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.8600       | 0.3750       | 4.9124         | 1.8421        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 89          | 0.8300       | 0.4600       | 4.8724         | 2.2413        | 0.0000 |
| 19.5        | 6                | 15         | Squat | 9.7600        | 0.1399           | 108         | 0.9300       | 0.6420       | 5.0057         | 3.2137        | 0.1411 |
| 20.0        | 6                | 15         | Squat | 9.7600        | 0.1399           | 109         | 0.9100       | 0.8460       | 4.9790         | 4.2123        | 0.0703 |
| 20.5        | 6                | 15         | Squat | 9.7600        | 0.1399           | 114         | 0.8500       | 1.2300       | 4.8991         | 6.0258        | 0.0368 |
| 21.0        | 6                | 15         | Squat | 9.7600        | 0.1399           | 108         | 0.8500       | 1.2630       | 4.8991         | 6.1875        | 0.0353 |
| 21.5        | 6                | 15         | Squat | 9.7600        | 0.1399           | 107         | 0.8200       | 1.2990       | 4.8591         | 6.3119        | 0.0342 |
| 22.0        | 6                | 15         | Squat | 9.7600        | 0.1399           | 109         | 0.8500       | 1.2710       | 4.8991         | 6.2267        | 0.0349 |
| 22.5        | 6                | 15         | Squat | 9.7600        | 0.1399           | 108         | 0.8300       | 1.2200       | 4.8724         | 5.9443        | 0.0376 |
| 23.0        | 6                | 15         | Squat | 9.7600        | 0.1399           | 105         | 0.8600       | 1.1900       | 4.9124         | 5.8457        | 0.0386 |

|      |   |    |       |        |        |     |        |        |        |        |        |
|------|---|----|-------|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 6 | 15 | Squat | 9.7600 | 0.1399 | 109 | 0.8400 | 1.1960 | 4.8857 | 5.8433 | 0.0386 |
| 24.0 | 6 | 15 | Squat | 9.7600 | 0.1399 | 110 | 0.8500 | 1.1550 | 4.8991 | 5.6584 | 0.0407 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 110 | 0.8400 | 1.3870 | 4.8857 | 6.7765 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 94  | 0.9000 | 0.9430 | 4.9657 | 4.6827 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 88  | 0.9500 | 0.6700 | 5.0324 | 3.3717 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 90  | 1.0200 | 0.4440 | 5.1257 | 2.2758 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 92  | 0.9500 | 0.4310 | 5.0324 | 2.1689 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 86  | 0.8400 | 0.4560 | 4.8857 | 2.2279 | 0.0000 |



Subject 4, Task 3, Trial 3, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8100       | 0.4720       | 4.8457         | 2.2872        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8300       | 0.3400       | 4.8724         | 1.6566        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.8200       | 0.3240       | 4.8591         | 1.5743        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.8100       | 0.3290       | 4.8457         | 1.5942        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.8500       | 0.3890       | 4.8991         | 1.9057        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.8200       | 0.3610       | 4.8591         | 1.7541        | 0.0000 |
| 3.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 110         | 0.9300       | 0.5630       | 5.0057         | 2.8182        | 0.0586 |
| 4.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 98          | 0.8900       | 0.5760       | 4.9524         | 2.8526        | 0.0563 |
| 4.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 98          | 0.8800       | 0.6610       | 4.9390         | 3.2647        | 0.0384 |
| 5.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 95          | 0.8200       | 0.6500       | 4.8591         | 3.1584        | 0.0418 |
| 5.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 98          | 0.7800       | 0.7480       | 4.8057         | 3.5947        | 0.0306 |
| 6.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 98          | 0.8000       | 0.7210       | 4.8324         | 3.4842        | 0.0328 |
| 6.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 92          | 0.7700       | 0.6910       | 4.7924         | 3.3116        | 0.0370 |
| 7.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 96          | 0.7900       | 0.7320       | 4.8191         | 3.5276        | 0.0319 |
| 7.5         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 99          | 0.7800       | 0.6390       | 4.8057         | 3.0709        | 0.0451 |
| 8.0         | 6                | 5          | Arm   | 3.4700        | 0.0497           | 101         | 0.8100       | 0.7570       | 4.8457         | 3.6682        | 0.0293 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 92          | 0.8000       | 0.7680       | 4.8324         | 3.7113        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.7900       | 0.5270       | 4.8191         | 2.5396        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.8100       | 0.4100       | 4.8457         | 1.9867        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.8100       | 0.3180       | 4.8457         | 1.5409        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8000       | 0.3650       | 4.8324         | 1.7638        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8000       | 0.3530       | 4.8324         | 1.7058        | 0.0000 |
| 11.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 88          | 0.8200       | 0.6570       | 4.8591         | 3.1924        | 0.0790 |
| 12.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.8500       | 0.7180       | 4.8991         | 3.5175        | 0.0619 |
| 12.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.8000       | 0.8470       | 4.8324         | 4.0930        | 0.0448 |
| 13.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 96          | 0.7800       | 0.9580       | 4.8057         | 4.6039        | 0.0359 |
| 13.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.7800       | 0.9720       | 4.8057         | 4.6712        | 0.0350 |
| 14.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.7600       | 1.0000       | 4.7791         | 4.7791        | 0.0337 |
| 14.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 104         | 0.7800       | 0.9350       | 4.8057         | 4.4934        | 0.0375 |
| 15.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 101         | 0.7800       | 1.0390       | 4.8057         | 4.9932        | 0.0313 |
| 15.5        | 4                | 15         | Squat | 6.5000        | 0.0931           | 106         | 0.8000       | 0.9790       | 4.8324         | 4.7309        | 0.0343 |
| 16.0        | 4                | 15         | Squat | 6.5000        | 0.0931           | 105         | 0.8000       | 0.9410       | 4.8324         | 4.5473        | 0.0368 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 90          | 0.7600       | 1.0250       | 4.7791         | 4.8986        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.8000       | 0.7040       | 4.8324         | 3.4020        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 92          | 0.8600       | 0.5420       | 4.9124         | 2.6625        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.9200       | 0.4570       | 4.9924         | 2.2815        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 91          | 0.9200       | 0.3980       | 4.9924         | 1.9870        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.8200       | 0.4690       | 4.8591         | 2.2789        | 0.0000 |



## Subject 4, Test 3

| Equation Type | Equation                                    | Equation Parameters |        |       |         |
|---------------|---------------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.23   | alfa= | 0.58    |
| i/t           |                                             |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                         |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.72   | alfa= | 0.32    |
| gain          | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0343 | C =   | -2.2578 |
| i/t           |                                             |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                         |                     |        |       |         |
| gain          | $X9 = Y * X8$                               | Y =                 | 4.9115 |       |         |
| balance       | $X9 = X10 + X11 + X12$                      |                     |        |       |         |
| exogenous     |                                             |                     |        |       |         |
| regression    | $X10 = \text{Eff} * X11$                    | Eff =               | 0.0337 |       |         |
| exogenous     | $X12 = \text{RM}$                           | RM =                | 2.2311 |       |         |

|   |        |        |    |       |        |        |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.109  | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.4444 | 0.9444 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.034 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 2.2578  |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.2516 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.911 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.034 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 1 | X12 | = | 2.23107 |     |

Subject 4, Task 3, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.43 | -0.11 | -0.08 | 0.40 | 77.50  | -0.25 | -0.31 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 1.00  | 0.41 | -0.08 | -0.11 | 0.44 | 78.62  | -0.31 | -0.32 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 2.00  | 0.46 | -0.11 | -0.10 | 0.45 | 78.94  | -0.32 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 3.00  | 0.45 | -0.10 | -0.11 | 0.45 | 79.03  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 4.00  | 0.52 | -0.11 | -0.14 | 0.55 | 81.97  | -0.33 | -0.43 | 0.66 | 3.24 | 0.03 | 0.98 | 2.23 |
| 5.00  | 0.62 | -0.14 | -0.15 | 0.63 | 84.18  | -0.43 | -0.46 | 0.66 | 3.24 | 0.03 | 0.98 | 2.23 |
| 6.00  | 0.65 | -0.15 | -0.15 | 0.65 | 84.81  | -0.46 | -0.47 | 0.66 | 3.24 | 0.03 | 0.98 | 2.23 |
| 7.00  | 0.66 | -0.15 | -0.15 | 0.66 | 84.99  | -0.47 | -0.47 | 0.66 | 3.24 | 0.03 | 0.98 | 2.23 |
| 8.00  | 0.66 | -0.15 | -0.15 | 0.66 | 85.04  | -0.47 | -0.47 | 0.66 | 3.24 | 0.03 | 0.98 | 2.23 |
| 9.00  | 0.60 | -0.15 | -0.12 | 0.56 | 82.15  | -0.47 | -0.37 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 10.00 | 0.49 | -0.12 | -0.11 | 0.48 | 79.95  | -0.37 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 11.00 | 0.47 | -0.11 | -0.11 | 0.46 | 79.32  | -0.34 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 12.00 | 0.52 | -0.11 | -0.14 | 0.55 | 81.89  | -0.33 | -0.43 | 0.65 | 3.18 | 0.03 | 0.92 | 2.23 |
| 13.00 | 0.61 | -0.14 | -0.15 | 0.62 | 83.91  | -0.43 | -0.46 | 0.65 | 3.18 | 0.03 | 0.92 | 2.23 |
| 14.00 | 0.64 | -0.15 | -0.15 | 0.64 | 84.49  | -0.46 | -0.46 | 0.65 | 3.18 | 0.03 | 0.92 | 2.23 |
| 15.00 | 0.65 | -0.15 | -0.15 | 0.65 | 84.66  | -0.46 | -0.47 | 0.65 | 3.18 | 0.03 | 0.92 | 2.23 |
| 16.00 | 0.65 | -0.15 | -0.15 | 0.65 | 84.71  | -0.47 | -0.47 | 0.65 | 3.18 | 0.03 | 0.92 | 2.23 |
| 17.00 | 0.59 | -0.15 | -0.12 | 0.55 | 81.97  | -0.47 | -0.37 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 18.00 | 0.49 | -0.12 | -0.11 | 0.48 | 79.90  | -0.37 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 19.00 | 0.47 | -0.11 | -0.11 | 0.46 | 79.31  | -0.34 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 20.00 | 0.55 | -0.11 | -0.15 | 0.60 | 83.25  | -0.33 | -0.48 | 0.74 | 3.66 | 0.05 | 1.38 | 2.23 |
| 21.00 | 0.69 | -0.15 | -0.17 | 0.70 | 86.31  | -0.48 | -0.52 | 0.74 | 3.66 | 0.05 | 1.38 | 2.23 |
| 22.00 | 0.73 | -0.17 | -0.17 | 0.73 | 87.19  | -0.52 | -0.53 | 0.74 | 3.66 | 0.05 | 1.38 | 2.23 |
| 23.00 | 0.74 | -0.17 | -0.17 | 0.74 | 87.44  | -0.53 | -0.53 | 0.74 | 3.66 | 0.05 | 1.38 | 2.23 |
| 24.00 | 0.74 | -0.17 | -0.17 | 0.74 | 87.51  | -0.53 | -0.54 | 0.74 | 3.66 | 0.05 | 1.38 | 2.23 |
| 25.00 | 0.65 | -0.17 | -0.12 | 0.60 | 83.42  | -0.54 | -0.39 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 26.00 | 0.51 | -0.12 | -0.11 | 0.50 | 80.31  | -0.39 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 27.00 | 0.47 | -0.11 | -0.11 | 0.47 | 79.42  | -0.34 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 28.00 | 0.46 | -0.11 | -0.11 | 0.46 | 79.17  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 29.00 | 0.46 | -0.11 | -0.10 | 0.46 | 79.10  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 30.00 | 0.45 | -0.10 | -0.10 | 0.45 | 79.08  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 31.00 | 0.75 | -0.10 | -0.26 | 0.91 | 92.24  | -0.33 | -0.81 | 1.38 | 6.80 | 0.15 | 4.42 | 2.23 |
| 32.00 | 1.21 | -0.26 | -0.30 | 1.25 | 102.19 | -0.81 | -0.94 | 1.38 | 6.80 | 0.15 | 4.42 | 2.23 |
| 33.00 | 1.33 | -0.30 | -0.31 | 1.34 | 105.04 | -0.94 | -0.98 | 1.38 | 6.80 | 0.15 | 4.42 | 2.23 |
| 34.00 | 1.37 | -0.31 | -0.32 | 1.37 | 105.85 | -0.98 | -0.99 | 1.38 | 6.80 | 0.15 | 4.42 | 2.23 |
| 35.00 | 1.38 | -0.32 | -0.32 | 1.38 | 106.08 | -0.99 | -1.00 | 1.38 | 6.80 | 0.15 | 4.42 | 2.23 |
| 36.00 | 1.09 | -0.32 | -0.16 | 0.93 | 92.98  | -1.00 | -0.52 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 37.00 | 0.63 | -0.16 | -0.12 | 0.59 | 83.04  | -0.52 | -0.38 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 38.00 | 0.51 | -0.12 | -0.11 | 0.49 | 80.20  | -0.38 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 39.00 | 0.66 | -0.11 | -0.21 | 0.77 | 88.17  | -0.34 | -0.65 | 1.07 | 5.27 | 0.10 | 2.94 | 2.23 |
| 40.00 | 0.96 | -0.21 | -0.23 | 0.99 | 94.57  | -0.65 | -0.74 | 1.07 | 5.27 | 0.10 | 2.94 | 2.23 |
| 41.00 | 1.04 | -0.23 | -0.25 | 1.05 | 96.40  | -0.74 | -0.76 | 1.07 | 5.27 | 0.10 | 2.94 | 2.23 |
| 42.00 | 1.07 | -0.25 | -0.25 | 1.07 | 96.92  | -0.76 | -0.77 | 1.07 | 5.27 | 0.10 | 2.94 | 2.23 |
| 43.00 | 1.07 | -0.25 | -0.25 | 1.07 | 97.07  | -0.77 | -0.77 | 1.07 | 5.27 | 0.10 | 2.94 | 2.23 |
| 44.00 | 0.88 | -0.25 | -0.14 | 0.77 | 88.34  | -0.77 | -0.45 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 45.00 | 0.57 | -0.14 | -0.12 | 0.55 | 81.72  | -0.45 | -0.36 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |

|       |      |       |       |      |        |       |       |      |      |      |      |      |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 46.00 | 0.49 | -0.12 | -0.11 | 0.48 | 79.83  | -0.36 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 47.00 | 0.74 | -0.11 | -0.26 | 0.89 | 91.64  | -0.34 | -0.78 | 1.33 | 6.52 | 0.14 | 4.15 | 2.23 |
| 48.00 | 1.17 | -0.26 | -0.29 | 1.20 | 100.83 | -0.78 | -0.90 | 1.33 | 6.52 | 0.14 | 4.15 | 2.23 |
| 49.00 | 1.28 | -0.29 | -0.30 | 1.29 | 103.46 | -0.90 | -0.94 | 1.33 | 6.52 | 0.14 | 4.15 | 2.23 |
| 50.00 | 1.32 | -0.30 | -0.30 | 1.32 | 104.21 | -0.94 | -0.95 | 1.33 | 6.52 | 0.14 | 4.15 | 2.23 |
| 51.00 | 1.32 | -0.30 | -0.31 | 1.32 | 104.42 | -0.95 | -0.95 | 1.33 | 6.52 | 0.14 | 4.15 | 2.23 |
| 52.00 | 1.05 | -0.31 | -0.15 | 0.90 | 92.13  | -0.95 | -0.51 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 53.00 | 0.61 | -0.15 | -0.12 | 0.58 | 82.80  | -0.51 | -0.38 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 54.00 | 0.51 | -0.12 | -0.11 | 0.49 | 80.13  | -0.38 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 55.00 | 0.47 | -0.11 | -0.11 | 0.46 | 79.37  | -0.34 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 56.00 | 0.46 | -0.11 | -0.10 | 0.46 | 79.16  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 57.00 | 0.45 | -0.10 | -0.10 | 0.46 | 79.09  | -0.33 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 58.00 | 0.55 | -0.10 | -0.16 | 0.61 | 83.47  | -0.33 | -0.49 | 0.76 | 3.75 | 0.05 | 1.47 | 2.23 |
| 59.00 | 0.71 | -0.16 | -0.17 | 0.72 | 86.79  | -0.49 | -0.53 | 0.76 | 3.75 | 0.05 | 1.47 | 2.23 |
| 60.00 | 0.75 | -0.17 | -0.17 | 0.75 | 87.73  | -0.53 | -0.55 | 0.76 | 3.75 | 0.05 | 1.47 | 2.23 |
| 61.00 | 0.76 | -0.17 | -0.18 | 0.76 | 88.00  | -0.55 | -0.55 | 0.76 | 3.75 | 0.05 | 1.47 | 2.23 |
| 62.00 | 0.76 | -0.18 | -0.18 | 0.76 | 88.08  | -0.55 | -0.55 | 0.76 | 3.75 | 0.05 | 1.47 | 2.23 |
| 63.00 | 0.67 | -0.18 | -0.12 | 0.61 | 83.71  | -0.55 | -0.39 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 64.00 | 0.51 | -0.12 | -0.11 | 0.50 | 80.40  | -0.39 | -0.35 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 65.00 | 0.47 | -0.11 | -0.11 | 0.47 | 79.45  | -0.35 | -0.33 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 66.00 | 0.64 | -0.11 | -0.21 | 0.74 | 87.41  | -0.33 | -0.63 | 1.04 | 5.09 | 0.09 | 2.76 | 2.23 |
| 67.00 | 0.93 | -0.21 | -0.23 | 0.95 | 93.55  | -0.63 | -0.71 | 1.04 | 5.09 | 0.09 | 2.76 | 2.23 |
| 68.00 | 1.00 | -0.23 | -0.24 | 1.01 | 95.31  | -0.71 | -0.74 | 1.04 | 5.09 | 0.09 | 2.76 | 2.23 |
| 69.00 | 1.03 | -0.24 | -0.24 | 1.03 | 95.81  | -0.74 | -0.74 | 1.04 | 5.09 | 0.09 | 2.76 | 2.23 |
| 70.00 | 1.03 | -0.24 | -0.24 | 1.03 | 95.95  | -0.74 | -0.74 | 1.04 | 5.09 | 0.09 | 2.76 | 2.23 |
| 71.00 | 0.85 | -0.24 | -0.14 | 0.75 | 87.77  | -0.74 | -0.45 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 72.00 | 0.56 | -0.14 | -0.12 | 0.54 | 81.55  | -0.45 | -0.36 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |
| 73.00 | 0.49 | -0.12 | -0.11 | 0.48 | 79.78  | -0.36 | -0.34 | 0.45 | 2.23 | 0.00 | 0.00 | 2.23 |



Subject 5, Task 3, Trial 1, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.7700       | 0.3840       | 4.7924         | 1.8403        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 93          | 0.7700       | 0.3970       | 4.7924         | 1.9026        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.8100       | 0.2510       | 4.8457         | 1.2163        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 95          | 0.8000       | 0.3590       | 4.8324         | 1.7348        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 85          | 0.7400       | 0.4290       | 4.7524         | 2.0388        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 95          | 0.7600       | 0.3440       | 4.7791         | 1.6440        | 0.0000 |
| 3.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 102         | 0.8000       | 0.4020       | 4.8324         | 1.9426        | 0.6065 |
| 4.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 94          | 0.7700       | 0.6560       | 4.7924         | 3.1438        | 0.0728 |
| 4.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 104         | 0.7800       | 0.7180       | 4.8057         | 3.4505        | 0.0594 |
| 5.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 94          | 0.7600       | 0.7640       | 4.7791         | 3.6512        | 0.0530 |
| 5.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 97          | 0.7800       | 0.7450       | 4.8057         | 3.5803        | 0.0551 |
| 6.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 103         | 0.7700       | 0.7610       | 4.7924         | 3.6470        | 0.0532 |
| 6.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 96          | 0.7800       | 0.8460       | 4.8057         | 4.0657        | 0.0434 |
| 7.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 99          | 0.7700       | 0.7880       | 4.7924         | 3.7764        | 0.0497 |
| 7.5         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 104         | 0.7700       | 0.7410       | 4.7924         | 3.5512        | 0.0560 |
| 8.0         | 4                | 15         | Arm   | 6.9300        | 0.0993           | 98          | 0.7900       | 0.8590       | 4.8191         | 4.1396        | 0.0421 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.7900       | 0.6920       | 4.8191         | 3.3348        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.8200       | 0.5650       | 4.8591         | 2.7454        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 79          | 0.8500       | 0.4760       | 4.8991         | 2.3319        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.8400       | 0.4990       | 4.8857         | 2.4380        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.8300       | 0.4080       | 4.8724         | 1.9879        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 93          | 0.8400       | 0.3190       | 4.8857         | 1.5585        | 0.0000 |
| 11.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 110         | 0.8400       | 0.4340       | 4.8857         | 2.1204        | 0.1181 |
| 12.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 94          | 0.8600       | 0.4570       | 4.9124         | 2.2450        | 0.0898 |
| 12.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 105         | 0.8500       | 0.6990       | 4.8991         | 3.4244        | 0.0274 |
| 13.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 102         | 0.8000       | 0.6310       | 4.8324         | 3.0492        | 0.0352 |
| 13.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 105         | 0.8000       | 0.7550       | 4.8324         | 3.6485        | 0.0242 |
| 14.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 105         | 0.7800       | 0.7370       | 4.8057         | 3.5418        | 0.0257 |
| 14.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 105         | 0.8000       | 0.6750       | 4.8324         | 3.2619        | 0.0303 |
| 15.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 104         | 0.7700       | 0.7300       | 4.7924         | 3.4985        | 0.0263 |
| 15.5        | 6                | 5          | Squat | 3.2500        | 0.0466           | 103         | 0.7900       | 0.6590       | 4.8191         | 3.1758        | 0.0321 |
| 16.0        | 6                | 5          | Squat | 3.2500        | 0.0466           | 100         | 0.7900       | 0.7330       | 4.8191         | 3.5324        | 0.0258 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 94          | 0.7800       | 0.6780       | 4.8057         | 3.2583        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 90          | 0.7900       | 0.4750       | 4.8191         | 2.2891        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.8200       | 0.3490       | 4.8591         | 1.6958        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 86          | 0.8100       | 0.3240       | 4.8457         | 1.5700        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 84          | 0.8000       | 0.2590       | 4.8324         | 1.2516        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.8100       | 0.2820       | 4.8457         | 1.3665        | 0.0000 |
| 19.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 119         | 0.8100       | 0.3070       | 4.8457         | 1.4876        | -0.147 |
| 20.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 93          | 0.8300       | 0.4430       | 4.8724         | 2.1585        | 0.0739 |
| 20.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 101         | 0.8400       | 0.3940       | 4.8857         | 1.9250        | 0.1551 |
| 21.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 95          | 0.8400       | 0.4040       | 4.8857         | 1.9738        | 0.1261 |
| 21.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 95          | 0.8200       | 0.4000       | 4.8591         | 1.9436        | 0.1426 |
| 22.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 91          | 0.8100       | 0.4200       | 4.8457         | 2.0352        | 0.1021 |
| 22.5        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 93          | 0.7900       | 0.4150       | 4.8191         | 1.9999        | 0.1147 |
| 23.0        | 4                | 5          | Arm   | 2.3000        | 0.0330           | 96          | 0.7700       | 0.4490       | 4.7924         | 2.1518        | 0.0750 |

|      |   |   |     |        |        |     |        |        |        |        |        |
|------|---|---|-----|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 4 | 5 | Arm | 2.3000 | 0.0330 | 91  | 0.7900 | 0.3870 | 4.8191 | 1.8650 | 0.2162 |
| 24.0 | 4 | 5 | Arm | 2.3000 | 0.0330 | 96  | 0.7900 | 0.4100 | 4.8191 | 1.9758 | 0.1252 |
| 24.5 |   |   | Sit | 0.0000 | 0.0000 | 89  | 0.8100 | 0.5700 | 4.8457 | 2.7621 | 0.0000 |
| 25.0 |   |   | Sit | 0.0000 | 0.0000 | 89  | 0.8000 | 0.4340 | 4.8324 | 2.0973 | 0.0000 |
| 25.5 |   |   | Sit | 0.0000 | 0.0000 | 91  | 0.8200 | 0.3310 | 4.8591 | 1.6083 | 0.0000 |
| 26.0 |   |   | Sit | 0.0000 | 0.0000 | 93  | 0.8200 | 0.3360 | 4.8591 | 1.6326 | 0.0000 |
| 26.5 |   |   | Sit | 0.0000 | 0.0000 | 97  | 0.8100 | 0.2940 | 4.8457 | 1.4246 | 0.0000 |
| 27.0 |   |   | Sit | 0.0000 | 0.0000 | 101 | 0.7900 | 0.2850 | 4.8191 | 1.3734 | 0.0000 |

Subject 5, Task 3, Trial 2, experimentally collected data

| Time<br>min<br>**** | Freq.<br>Lif/min<br>**** | Load<br>Kg<br>**** | Type<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>**** | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|---------------------|--------------------------|--------------------|--------------|-----------------------|------------------|---------------------|----------------------|-------------|----------------|---------------|--------|
| 0.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 76                  | 0.8200               | 0.3210      | 4.8591         | 1.5598        | 0.0000 |
| 1.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 91                  | 0.7800               | 0.2600      | 4.8057         | 1.2495        | 0.0000 |
| 1.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 82                  | 0.7200               | 0.2580      | 4.7258         | 1.2192        | 0.0000 |
| 2.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 85                  | 0.7600               | 0.2930      | 4.7791         | 1.4003        | 0.0000 |
| 2.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 81                  | 0.7300               | 0.3460      | 4.7391         | 1.6397        | 0.0000 |
| 3.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 80                  | 0.7900               | 0.2810      | 4.8191         | 1.3542        | 0.0000 |
| 3.5                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 109                 | 0.8200               | 0.3330      | 4.8591         | 1.6181        | -0.195 |
| 4.0                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 99                  | 0.8100               | 0.4310      | 4.8457         | 2.0885        | 0.2310 |
| 4.5                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 97                  | 0.7700               | 0.3210      | 4.7924         | 1.5384        | -0.149 |
| 5.0                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 103                 | 0.7700               | 0.3830      | 4.7924         | 1.8355        | -1.317 |
| 5.5                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 99                  | 0.7400               | 0.4910      | 4.7524         | 2.3334        | 0.1081 |
| 6.0                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 101                 | 0.7500               | 0.4740      | 4.7658         | 2.2590        | 0.1289 |
| 6.5                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 102                 | 0.7500               | 0.4520      | 4.7658         | 2.1541        | 0.1770 |
| 7.0                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 104                 | 0.7500               | 0.4370      | 4.7658         | 2.0826        | 0.2375 |
| 7.5                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 97                  | 0.7500               | 0.4820      | 4.7658         | 2.2971        | 0.1173 |
| 8.0                 | 6                        | 5                  | Arm          | 3.4700                | 0.0497           | 90                  | 0.7400               | 0.4050      | 4.7524         | 1.9247        | 0.9662 |
| 8.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 85                  | 0.7300               | 0.5880      | 4.7391         | 2.7866        | 0.0000 |
| 9.0                 |                          |                    | Sit          | 0.0000                | 0.0000           | 78                  | 0.7300               | 0.5090      | 4.7391         | 2.4122        | 0.0000 |
| 9.5                 |                          |                    | Sit          | 0.0000                | 0.0000           | 78                  | 0.7700               | 0.4300      | 4.7924         | 2.0607        | 0.0000 |
| 10.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 80                  | 0.7600               | 0.3340      | 4.7791         | 1.5962        | 0.0000 |
| 10.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 95                  | 0.7500               | 0.3170      | 4.7658         | 1.5107        | 0.0000 |
| 11.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 83                  | 0.7700               | 0.4060      | 4.7924         | 1.9457        | 0.0000 |
| 11.5                | 4                        | 5                  | Squat        | 0.0000                | 0.0000           | 93                  | 0.8300               | 0.3070      | 4.8724         | 1.4958        | 0.0000 |
| 12.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 90                  | 0.7900               | 0.4010      | 4.8191         | 1.9324        | 0.3996 |
| 12.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 86                  | 0.7900               | 0.4740      | 4.8191         | 2.2842        | 0.0724 |
| 13.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 105                 | 0.7600               | 0.5570      | 4.7791         | 2.6619        | 0.0385 |
| 13.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 86                  | 0.7500               | 0.5930      | 4.7658         | 2.8261        | 0.0320 |
| 14.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 92                  | 0.7500               | 0.5450      | 4.7658         | 2.5973        | 0.0419 |
| 14.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 93                  | 0.7300               | 0.8830      | 4.7391         | 4.1846        | 0.0133 |
| 15.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 95                  | 0.7600               | 0.6760      | 4.7791         | 3.2307        | 0.0226 |
| 15.5                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 91                  | 0.7300               | 0.5380      | 4.7391         | 2.5496        | 0.0447 |
| 16.0                | 4                        | 5                  | Squat        | 2.1700                | 0.0311           | 100                 | 0.7300               | 0.6000      | 4.7391         | 2.8435        | 0.0314 |
| 16.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 86                  | 0.7100               | 0.7490      | 4.7124         | 3.5296        | 0.0000 |
| 17.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 86                  | 0.7400               | 0.6410      | 4.7524         | 3.0463        | 0.0000 |
| 17.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 84                  | 0.7300               | 0.4440      | 4.7391         | 2.1042        | 0.0000 |
| 18.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 82                  | 0.7400               | 0.3930      | 4.7524         | 1.8677        | 0.0000 |
| 18.5                |                          |                    | Sit          | 0.0000                | 0.0000           | 81                  | 0.7400               | 0.2980      | 4.7524         | 1.4162        | 0.0000 |
| 19.0                |                          |                    | Sit          | 0.0000                | 0.0000           | 84                  | 0.7500               | 0.4540      | 4.7658         | 2.1637        | 0.0000 |
| 19.5                | 6                        | 15                 | Squat        | 0.0000                | 0.0000           | 112                 | 0.8300               | 0.3560      | 4.8724         | 1.7346        | 0.0000 |
| 20.0                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 108                 | 0.7300               | 0.5980      | 4.7391         | 2.8340        | 0.1607 |
| 20.5                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 103                 | 0.7500               | 0.7570      | 4.7658         | 3.6077        | 0.0851 |
| 21.0                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 104                 | 0.7200               | 0.7350      | 4.7258         | 3.4734        | 0.0926 |
| 21.5                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 107                 | 0.7100               | 0.9180      | 4.7124         | 4.3260        | 0.0592 |
| 22.0                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 91                  | 0.7100               | 0.9630      | 4.7124         | 4.5381        | 0.0543 |
| 22.5                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 102                 | 0.7100               | 0.7590      | 4.7124         | 3.5767        | 0.0867 |
| 23.0                | 6                        | 15                 | Squat        | 9.7600                | 0.1399           | 109                 | 0.7200               | 0.8730      | 4.7258         | 4.1256        | 0.0647 |

|      |   |    |       |        |        |     |        |        |        |        |        |
|------|---|----|-------|--------|--------|-----|--------|--------|--------|--------|--------|
| 23.5 | 6 | 15 | Squat | 9.7600 | 0.1399 | 105 | 0.7100 | 0.8690 | 4.7124 | 4.0951 | 0.0656 |
| 24.0 | 6 | 15 | Squat | 9.7600 | 0.1399 | 100 | 0.7400 | 0.6960 | 4.7524 | 3.3077 | 0.1040 |
| 24.5 |   |    | Sit   | 0.0000 | 0.0000 | 90  | 0.7100 | 0.9730 | 4.7124 | 4.5852 | 0.0000 |
| 25.0 |   |    | Sit   | 0.0000 | 0.0000 | 79  | 0.7100 | 0.6830 | 4.7124 | 3.2186 | 0.0000 |
| 25.5 |   |    | Sit   | 0.0000 | 0.0000 | 79  | 0.7800 | 0.5670 | 4.8057 | 2.7249 | 0.0000 |
| 26.0 |   |    | Sit   | 0.0000 | 0.0000 | 82  | 0.7900 | 0.4270 | 4.8191 | 2.0577 | 0.0000 |
| 26.5 |   |    | Sit   | 0.0000 | 0.0000 | 87  | 0.7900 | 0.4190 | 4.8191 | 2.0192 | 0.0000 |
| 27.0 |   |    | Sit   | 0.0000 | 0.0000 | 87  | 0.7900 | 0.4350 | 4.8191 | 2.0963 | 0.0000 |



Subject 5, Task 3, Trial 3, experimentally collected data

| Time<br>min | Freq.<br>Lif/min | Load<br>Kg | Type  | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>l/min | VO2<br>Kcal/l | Eff    |
|-------------|------------------|------------|-------|---------------|------------------|-------------|--------------|--------------|----------------|---------------|--------|
| ****        | ****             | ****       | ****  | ****          |                  | ****        | ****         | ****         |                |               |        |
| 0.5         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8600       | 0.3460       | 4.9124         | 1.6997        | 0.0000 |
| 1.0         |                  |            | Sit   | 0.0000        | 0.0000           | 81          | 0.8800       | 0.2890       | 4.9390         | 1.4274        | 0.0000 |
| 1.5         |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.9000       | 0.3610       | 4.9657         | 1.7926        | 0.0000 |
| 2.0         |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.9000       | 0.2810       | 4.9657         | 1.3954        | 0.0000 |
| 2.5         |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.9100       | 0.2820       | 4.9790         | 1.4041        | 0.0000 |
| 3.0         |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.9100       | 0.3170       | 4.9790         | 1.5784        | 0.0000 |
| 3.5         | 4                | 15         | Squat | 6.5000        | 0.0931           | 97          | 0.9700       | 0.4050       | 5.0590         | 2.0489        | 0.2568 |
| 4.0         | 4                | 15         | Squat | 6.5000        | 0.0931           | 96          | 0.9300       | 0.5070       | 5.0057         | 2.5379        | 0.1094 |
| 4.5         | 4                | 15         | Squat | 6.5000        | 0.0931           | 97          | 0.8500       | 0.5430       | 4.8991         | 2.6602        | 0.0956 |
| 5.0         | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.8100       | 0.6290       | 4.8457         | 3.0480        | 0.0684 |
| 5.5         | 4                | 15         | Squat | 6.5000        | 0.0931           | 95          | 0.7900       | 0.6150       | 4.8191         | 2.9637        | 0.0729 |
| 6.0         | 4                | 15         | Squat | 6.5000        | 0.0931           | 100         | 0.7800       | 0.6750       | 4.8057         | 3.2439        | 0.0598 |
| 6.5         | 4                | 15         | Squat | 6.5000        | 0.0931           | 96          | 0.7800       | 0.7030       | 4.8057         | 3.3784        | 0.0550 |
| 7.0         | 4                | 15         | Squat | 6.5000        | 0.0931           | 97          | 0.7900       | 0.6670       | 4.8191         | 3.2143        | 0.0610 |
| 7.5         | 4                | 15         | Squat | 6.5000        | 0.0931           | 99          | 0.7600       | 0.6130       | 4.7791         | 2.9296        | 0.0749 |
| 8.0         | 4                | 15         | Squat | 6.5000        | 0.0931           | 102         | 0.7800       | 0.7040       | 4.8057         | 3.3832        | 0.0549 |
| 8.5         |                  |            | Sit   | 0.0000        | 0.0000           | 88          | 0.7800       | 0.7590       | 4.8057         | 3.6476        | 0.0000 |
| 9.0         |                  |            | Sit   | 0.0000        | 0.0000           | 80          | 0.7800       | 0.6080       | 4.8057         | 2.9219        | 0.0000 |
| 9.5         |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.8200       | 0.4140       | 4.8591         | 2.0117        | 0.0000 |
| 10.0        |                  |            | Sit   | 0.0000        | 0.0000           | 75          | 0.8400       | 0.3270       | 4.8857         | 1.5976        | 0.0000 |
| 10.5        |                  |            | Sit   | 0.0000        | 0.0000           | 83          | 0.8500       | 0.2840       | 4.8991         | 1.3913        | 0.0000 |
| 11.0        |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.8500       | 0.3240       | 4.8991         | 1.5873        | 0.0000 |
| 11.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 102         | 0.8600       | 0.2650       | 4.9124         | 1.3018        | -0.338 |
| 12.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 103         | 0.8800       | 0.5240       | 4.9390         | 2.5881        | 0.1762 |
| 12.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 107         | 0.8400       | 0.6220       | 4.8857         | 3.0389        | 0.1149 |
| 13.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 102         | 0.8300       | 0.6960       | 4.8724         | 3.3912        | 0.0904 |
| 13.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 98          | 0.8400       | 0.6230       | 4.8857         | 3.0438        | 0.1145 |
| 14.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 97          | 0.8000       | 0.6310       | 4.8324         | 3.0492        | 0.1140 |
| 14.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 99          | 0.8100       | 0.6480       | 4.8457         | 3.1400        | 0.1066 |
| 15.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 99          | 0.7900       | 0.8570       | 4.8191         | 4.1299        | 0.0624 |
| 15.5        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 103         | 0.8000       | 0.6730       | 4.8324         | 3.2522        | 0.0987 |
| 16.0        | 6                | 15         | Arm   | 10.4000       | 0.1490           | 104         | 0.8200       | 0.7530       | 4.8591         | 3.6589        | 0.0777 |
| 16.5        |                  |            | Sit   | 0.0000        | 0.0000           | 87          | 0.8300       | 0.8050       | 4.8724         | 3.9223        | 0.0000 |
| 17.0        |                  |            | Sit   | 0.0000        | 0.0000           | 77          | 0.8900       | 0.6020       | 4.9524         | 2.9813        | 0.0000 |
| 17.5        |                  |            | Sit   | 0.0000        | 0.0000           | 76          | 0.9200       | 0.3880       | 4.9924         | 1.9370        | 0.0000 |
| 18.0        |                  |            | Sit   | 0.0000        | 0.0000           | 82          | 0.9100       | 0.3040       | 4.9790         | 1.5136        | 0.0000 |
| 18.5        |                  |            | Sit   | 0.0000        | 0.0000           | 89          | 0.8900       | 0.2760       | 4.9524         | 1.3669        | 0.0000 |
| 19.0        |                  |            | Sit   | 0.0000        | 0.0000           | 78          | 0.8900       | 0.3110       | 4.9524         | 1.5402        | 0.0000 |

Subject 5, Test 3

|               |                                             |                     |        |       |         |
|---------------|---------------------------------------------|---------------------|--------|-------|---------|
| Equation Type | Equation                                    | Equation Parameters |        |       |         |
| regression    | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.23   | alfa= | 0.58    |
| i/t           |                                             |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                         |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.72   | alfa= | 0.32    |
| gain          | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0287 | C =   | -2.4770 |
| i/t           |                                             |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                         |                     |        |       |         |
| gain          | $X9 = Y * X8$                               | Y =                 | 4.7587 |       |         |
| balance       | $X9 = X10 + X11 + X12$                      |                     |        |       |         |
| exogenous     |                                             |                     |        |       |         |
| regression    | $X10 = \text{Eff} * X11$                    | Eff =               | 0.0682 |       |         |
| exogenous     | $X12 = \text{RM}$                           | RM =                | 1.6858 |       |         |

|   |        |        |    |       |        |        |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 2.5217 | 1.8261 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.109  | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.4444 | 0.9444 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 2.47696 |     |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.2516 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 4.759 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0.068 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0     | 1 | 1 | X12 | = | 1.68579 |     |

Subject 5, Task 3, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.40 | -0.11 | -0.07 | 0.35 | 98.43  | -0.25 | -0.25 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 1.00  | 0.33 | -0.07 | -0.09 | 0.35 | 98.49  | -0.25 | -0.25 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 2.00  | 0.37 | -0.09 | -0.08 | 0.35 | 98.50  | -0.25 | -0.25 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 3.00  | 0.35 | -0.08 | -0.08 | 0.35 | 98.51  | -0.25 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 4.00  | 0.46 | -0.08 | -0.14 | 0.51 | 104.03 | -0.26 | -0.42 | 0.68 | 3.24 | 0.10 | 1.46 | 1.69 |
| 5.00  | 0.62 | -0.14 | -0.15 | 0.63 | 108.21 | -0.42 | -0.47 | 0.68 | 3.24 | 0.10 | 1.46 | 1.69 |
| 6.00  | 0.66 | -0.15 | -0.16 | 0.67 | 109.41 | -0.47 | -0.48 | 0.68 | 3.24 | 0.10 | 1.46 | 1.69 |
| 7.00  | 0.68 | -0.16 | -0.16 | 0.68 | 109.75 | -0.48 | -0.49 | 0.68 | 3.24 | 0.10 | 1.46 | 1.69 |
| 8.00  | 0.68 | -0.16 | -0.16 | 0.68 | 109.84 | -0.49 | -0.49 | 0.68 | 3.24 | 0.10 | 1.46 | 1.69 |
| 9.00  | 0.58 | -0.16 | -0.10 | 0.52 | 104.35 | -0.49 | -0.32 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 10.00 | 0.41 | -0.10 | -0.09 | 0.40 | 100.18 | -0.32 | -0.27 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 11.00 | 0.37 | -0.09 | -0.08 | 0.37 | 98.99  | -0.27 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 12.00 | 0.41 | -0.08 | -0.11 | 0.43 | 101.24 | -0.26 | -0.34 | 0.51 | 2.42 | 0.05 | 0.68 | 1.69 |
| 13.00 | 0.48 | -0.11 | -0.11 | 0.49 | 103.10 | -0.34 | -0.36 | 0.51 | 2.42 | 0.05 | 0.68 | 1.69 |
| 14.00 | 0.50 | -0.11 | -0.12 | 0.50 | 103.63 | -0.36 | -0.36 | 0.51 | 2.42 | 0.05 | 0.68 | 1.69 |
| 15.00 | 0.51 | -0.12 | -0.12 | 0.51 | 103.78 | -0.36 | -0.36 | 0.51 | 2.42 | 0.05 | 0.68 | 1.69 |
| 16.00 | 0.51 | -0.12 | -0.12 | 0.51 | 103.83 | -0.36 | -0.37 | 0.51 | 2.42 | 0.05 | 0.68 | 1.69 |
| 17.00 | 0.46 | -0.12 | -0.09 | 0.43 | 101.25 | -0.37 | -0.29 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 18.00 | 0.38 | -0.09 | -0.08 | 0.38 | 99.29  | -0.29 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 19.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.73  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 20.00 | 0.39 | -0.08 | -0.10 | 0.41 | 100.41 | -0.26 | -0.31 | 0.46 | 2.20 | 0.03 | 0.48 | 1.69 |
| 21.00 | 0.44 | -0.10 | -0.10 | 0.45 | 101.75 | -0.31 | -0.33 | 0.46 | 2.20 | 0.03 | 0.48 | 1.69 |
| 22.00 | 0.46 | -0.10 | -0.11 | 0.46 | 102.13 | -0.33 | -0.33 | 0.46 | 2.20 | 0.03 | 0.48 | 1.69 |
| 23.00 | 0.46 | -0.11 | -0.11 | 0.46 | 102.24 | -0.33 | -0.33 | 0.46 | 2.20 | 0.03 | 0.48 | 1.69 |
| 24.00 | 0.46 | -0.11 | -0.11 | 0.46 | 102.27 | -0.33 | -0.33 | 0.46 | 2.20 | 0.03 | 0.48 | 1.69 |
| 25.00 | 0.43 | -0.11 | -0.09 | 0.41 | 100.45 | -0.33 | -0.28 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 26.00 | 0.37 | -0.09 | -0.08 | 0.37 | 99.06  | -0.28 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 27.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.67  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 28.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.56  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 29.00 | 0.35 | -0.08 | -0.08 | 0.35 | 98.52  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 30.00 | 0.35 | -0.08 | -0.08 | 0.35 | 98.52  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 31.00 | 0.41 | -0.08 | -0.11 | 0.43 | 101.28 | -0.26 | -0.34 | 0.52 | 2.46 | 0.05 | 0.73 | 1.69 |
| 32.00 | 0.49 | -0.11 | -0.12 | 0.49 | 103.37 | -0.34 | -0.36 | 0.52 | 2.46 | 0.05 | 0.73 | 1.69 |
| 33.00 | 0.51 | -0.12 | -0.12 | 0.51 | 103.97 | -0.36 | -0.37 | 0.52 | 2.46 | 0.05 | 0.73 | 1.69 |
| 34.00 | 0.52 | -0.12 | -0.12 | 0.52 | 104.14 | -0.37 | -0.37 | 0.52 | 2.46 | 0.05 | 0.73 | 1.69 |
| 35.00 | 0.52 | -0.12 | -0.12 | 0.52 | 104.19 | -0.37 | -0.37 | 0.52 | 2.46 | 0.05 | 0.73 | 1.69 |
| 36.00 | 0.47 | -0.12 | -0.09 | 0.44 | 101.43 | -0.37 | -0.29 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 37.00 | 0.38 | -0.09 | -0.08 | 0.38 | 99.35  | -0.29 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 38.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.75  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 39.00 | 0.37 | -0.08 | -0.09 | 0.38 | 99.44  | -0.26 | -0.28 | 0.41 | 1.93 | 0.02 | 0.23 | 1.69 |
| 40.00 | 0.41 | -0.09 | -0.10 | 0.42 | 100.91 | -0.28 | -0.32 | 0.46 | 2.17 | 0.03 | 0.46 | 1.69 |
| 41.00 | 0.44 | -0.10 | -0.10 | 0.45 | 101.74 | -0.32 | -0.32 | 0.46 | 2.17 | 0.03 | 0.46 | 1.69 |
| 42.00 | 0.45 | -0.10 | -0.10 | 0.45 | 101.98 | -0.32 | -0.33 | 0.46 | 2.17 | 0.03 | 0.46 | 1.69 |
| 43.00 | 0.46 | -0.10 | -0.10 | 0.46 | 102.05 | -0.33 | -0.33 | 0.46 | 2.17 | 0.03 | 0.46 | 1.69 |
| 44.00 | 0.42 | -0.10 | -0.09 | 0.41 | 100.34 | -0.33 | -0.28 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 45.00 | 0.37 | -0.09 | -0.08 | 0.37 | 99.03  | -0.28 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |



|       |      |       |       |      |        |       |       |      |      |      |      |      |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 46.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.66  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 47.00 | 0.43 | -0.08 | -0.12 | 0.47 | 102.44 | -0.26 | -0.37 | 0.58 | 2.78 | 0.07 | 1.03 | 1.69 |
| 48.00 | 0.61 | -0.12 | -0.17 | 0.66 | 109.24 | -0.37 | -0.53 | 0.81 | 3.88 | 0.14 | 2.05 | 1.69 |
| 49.00 | 0.76 | -0.17 | -0.18 | 0.77 | 113.02 | -0.53 | -0.57 | 0.81 | 3.88 | 0.14 | 2.05 | 1.69 |
| 50.00 | 0.80 | -0.18 | -0.19 | 0.80 | 114.10 | -0.57 | -0.58 | 0.81 | 3.88 | 0.14 | 2.05 | 1.69 |
| 51.00 | 0.81 | -0.19 | -0.19 | 0.81 | 114.40 | -0.58 | -0.59 | 0.81 | 3.88 | 0.14 | 2.05 | 1.69 |
| 52.00 | 0.67 | -0.19 | -0.11 | 0.59 | 106.71 | -0.59 | -0.35 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 53.00 | 0.44 | -0.11 | -0.09 | 0.42 | 100.85 | -0.35 | -0.28 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 54.00 | 0.38 | -0.09 | -0.08 | 0.37 | 99.18  | -0.28 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 55.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.70  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 56.00 | 0.36 | -0.08 | -0.08 | 0.36 | 98.57  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 57.00 | 0.35 | -0.08 | -0.08 | 0.35 | 98.53  | -0.26 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 58.00 | 0.45 | -0.08 | -0.13 | 0.50 | 103.70 | -0.26 | -0.41 | 0.66 | 3.14 | 0.09 | 1.37 | 1.69 |
| 59.00 | 0.60 | -0.13 | -0.15 | 0.62 | 107.61 | -0.41 | -0.46 | 0.66 | 3.14 | 0.09 | 1.37 | 1.69 |
| 60.00 | 0.64 | -0.15 | -0.15 | 0.65 | 108.73 | -0.46 | -0.47 | 0.66 | 3.14 | 0.09 | 1.37 | 1.69 |
| 61.00 | 0.66 | -0.15 | -0.15 | 0.66 | 109.05 | -0.47 | -0.47 | 0.66 | 3.14 | 0.09 | 1.37 | 1.69 |
| 62.00 | 0.66 | -0.15 | -0.15 | 0.66 | 109.14 | -0.47 | -0.48 | 0.66 | 3.14 | 0.09 | 1.37 | 1.69 |
| 63.00 | 0.56 | -0.15 | -0.10 | 0.51 | 103.99 | -0.48 | -0.32 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 64.00 | 0.41 | -0.10 | -0.09 | 0.40 | 100.08 | -0.32 | -0.27 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 65.00 | 0.37 | -0.09 | -0.08 | 0.37 | 98.96  | -0.27 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 66.00 | 0.51 | -0.08 | -0.17 | 0.60 | 106.93 | -0.26 | -0.51 | 0.84 | 4.02 | 0.15 | 2.19 | 1.69 |
| 67.00 | 0.76 | -0.17 | -0.18 | 0.77 | 113.11 | -0.51 | -0.58 | 0.84 | 4.02 | 0.15 | 2.19 | 1.69 |
| 68.00 | 0.82 | -0.18 | -0.19 | 0.82 | 114.87 | -0.58 | -0.60 | 0.84 | 4.02 | 0.15 | 2.19 | 1.69 |
| 69.00 | 0.84 | -0.19 | -0.19 | 0.84 | 115.38 | -0.60 | -0.61 | 0.84 | 4.02 | 0.15 | 2.19 | 1.69 |
| 70.00 | 0.84 | -0.19 | -0.19 | 0.84 | 115.52 | -0.61 | -0.61 | 0.84 | 4.02 | 0.15 | 2.19 | 1.69 |
| 71.00 | 0.69 | -0.19 | -0.11 | 0.61 | 107.27 | -0.61 | -0.36 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 72.00 | 0.44 | -0.11 | -0.09 | 0.43 | 101.01 | -0.36 | -0.28 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |
| 73.00 | 0.38 | -0.09 | -0.08 | 0.37 | 99.23  | -0.28 | -0.26 | 0.35 | 1.69 | 0.00 | 0.00 | 1.69 |

## APPENDIX E

### Task 4 Data

Subject 1, Task 4, Trial 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 78                  | 0.8200               | 0.3840               | 4.2779          | 1.6427          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 79                  | 0.8200               | 0.3760               | 4.2672          | 1.6045          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 79                  | 0.8300               | 0.3900               | 4.2859          | 1.6715          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 85                  | 0.8400               | 0.3830               | 4.2765          | 1.6379          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 77                  | 0.8500               | 0.3940               | 4.2912          | 1.6907          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 80                  | 0.7900               | 0.6260               | 4.6005          | 2.8799          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 107                 | 0.9600               | 1.0030               | 5.1030          | 5.1183          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 107                 | 0.9200               | 1.3370               | 5.5482          | 7.4180          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 105                 | 0.8700               | 1.3840               | 5.6109          | 7.7654          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 103                 | 0.8500               | 1.4880               | 5.7495          | 8.5553          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 104                 | 0.8600               | 1.4410               | 5.6869          | 8.1948          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 104                 | 0.8500               | 1.3630               | 5.5829          | 7.6095          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 104                 | 0.8600               | 1.4730               | 5.7295          | 8.4396          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 104                 | 0.8500               | 1.4580               | 5.7095          | 8.3245          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 107                 | 0.8600               | 1.4770               | 5.7348          | 8.4704          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 106                 | 0.8700               | 1.4590               | 5.7108          | 8.3321          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 98                  | 0.8600               | 1.2280               | 5.4029          | 6.6348          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 81                  | 0.9600               | 0.7960               | 4.8271          | 3.8423          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 83                  | 0.9500               | 0.6920               | 4.6884          | 3.2444          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 74                  | 0.9100               | 0.4710               | 4.3938          | 2.0695          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 75                  | 0.8900               | 0.3540               | 4.2379          | 1.5002          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 81                  | 0.8400               | 0.4330               | 4.3432          | 1.8806          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 103                 | 0.8800               | 0.9810               | 5.0737          | 4.9773          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 104                 | 0.9100               | 1.3710               | 5.5935          | 7.6687          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 103                 | 0.8800               | 1.6420               | 5.9548          | 9.7778          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 109                 | 0.8700               | 1.6480               | 5.9628          | 9.8267          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 101                 | 0.8700               | 1.5280               | 5.8028          | 8.8667          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 104                 | 0.8400               | 1.5360               | 5.8135          | 8.9295          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 104                 | 0.8500               | 1.6090               | 5.9108          | 9.5105          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 104                 | 0.8600               | 1.5330               | 5.8095          | 8.9059          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 103                 | 0.8600               | 1.6080               | 5.9095          | 9.5024          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 107                 | 0.8700               | 1.6720               | 5.9948          | 10.0233         | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 83                  | 0.8700               | 1.3480               | 5.5629          | 7.4988          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 79                  | 0.8900               | 0.7850               | 4.8124          | 3.7777          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 76                  | 0.9300               | 0.4780               | 4.4032          | 2.1047          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 84                  | 0.8900               | 0.5200               | 4.4592          | 2.3188          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 71                  | 0.9100               | 0.3960               | 4.2939          | 1.7004          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 83                  | 0.8700               | 0.4430               | 4.3565          | 1.9299          | 0.0000 |

Subject 1, Task 4, Trial 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 69                  | 0.7900               | 0.4530               | 4.8191          | 2.1830          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 66                  | 0.8000               | 0.3800               | 4.8324          | 1.8363          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 74                  | 0.8200               | 0.4830               | 4.8591          | 2.3469          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 72                  | 0.8100               | 0.3480               | 4.8457          | 1.6863          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 68                  | 0.8100               | 0.3650               | 4.8457          | 1.7687          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 68                  | 0.8000               | 0.2880               | 4.8324          | 1.3917          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 97                  | 0.8800               | 0.9650               | 4.9390          | 4.7662          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 114                 | 0.8700               | 1.4760               | 4.9257          | 7.2703          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 108                 | 0.8200               | 1.8880               | 4.8591          | 9.1739          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 108                 | 0.8100               | 1.8600               | 4.8457          | 9.0131          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 110                 | 0.8400               | 1.0140               | 4.8857          | 4.9541          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 112                 | 0.8600               | 1.9400               | 4.9124          | 9.5300          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 111                 | 0.8700               | 1.0160               | 4.9257          | 5.0045          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 108                 | 0.8700               | 1.9200               | 4.9257          | 9.4574          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 109                 | 0.8800               | 1.9950               | 4.9390          | 9.8534          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 107                 | 0.8800               | 1.8420               | 4.9390          | 9.0977          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 81                  | 0.8700               | 1.5300               | 4.9257          | 7.5363          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 76                  | 0.9500               | 0.8940               | 5.0324          | 4.4989          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 62                  | 0.9600               | 0.6370               | 5.0457          | 3.2141          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 60                  | 0.8900               | 0.3750               | 4.9524          | 1.8571          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 69                  | 0.8700               | 0.5050               | 4.9257          | 2.4875          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 66                  | 0.8700               | 0.3740               | 4.9257          | 1.8422          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 81                  | 0.9000               | 0.9440               | 4.9657          | 4.6876          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 88                  | 0.9300               | 1.0130               | 5.0057          | 5.0708          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 84                  | 0.8900               | 1.0900               | 4.9524          | 5.3981          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 92                  | 0.8600               | 1.0980               | 4.9124          | 5.3938          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 91                  | 0.8700               | 1.1570               | 4.9257          | 5.6990          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 90                  | 0.8700               | 1.1560               | 4.9257          | 5.6941          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 86                  | 0.8600               | 1.1540               | 4.9124          | 5.6689          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 90                  | 0.8400               | 1.1070               | 4.8857          | 5.4085          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 88                  | 0.8500               | 1.1940               | 4.8991          | 5.8495          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 90                  | 0.8500               | 1.3150               | 4.8991          | 6.4423          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 77                  | 0.8600               | 1.1320               | 4.9124          | 5.5608          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 71                  | 0.8800               | 0.6570               | 4.9390          | 3.2449          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 68                  | 0.8600               | 0.3450               | 4.9124          | 1.6948          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 78                  | 0.8500               | 0.4210               | 4.8991          | 2.0625          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 76                  | 0.8500               | 0.4770               | 4.8991          | 2.3368          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 71                  | 0.8600               | 0.4930               | 4.9124          | 2.4218          | 0.0000 |



## Subject 1, Test 4

| Equation Type | Equation                                    | Equation Parameters                      |
|---------------|---------------------------------------------|------------------------------------------|
| regression    | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | $D = 0.33 \quad \alpha = 0.60$           |
| i/t           |                                             |                                          |
| balance       | $X1 + X2 = X3 + X4$                         |                                          |
| gain          | $X4 = \text{Coef} * X5 + C$                 | $\text{Coef} = 0.0349 \quad C = -2.3197$ |
| exogenous     |                                             |                                          |
| i/t           |                                             |                                          |
| balance       | $X4 + X6 = X7 + X8$                         |                                          |
| regression    | $X8 = 1/D (\alpha * X6 + (1-\alpha) * X7)$  | $D = 0.76 \quad \alpha = 0.21$           |
| gain          | $X9 = Y * X8$                               | $Y = 5.0325$                             |
| balance       | $X9 = X10 + X11 + X12$                      |                                          |
| regression    | $X10 = \text{Eff} * X11$                    | $\text{Eff} = 0.0000$                    |
| exogenous     | $X12 = \text{RM}$                           | $\text{RM} = 2.0725$                     |

|   |        |        |    |       |        |        |       |   |    |    |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|---|----|----|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.035 | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X4  | = | 2.3197  |     |
| 0 | 0      | 0      | 0  | 1     | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X5  | = | 64.5    | ex  |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0 | 0  | 0  | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0 | 0  | 0  | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0.2763 | 1.0395 | -1    | 0 | 0  | 0  | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | -5.03 | 1 | 0  | 0  | 0 | 0 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0 | -1 | 1  | 1 | 1 | X10 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0 | 0  | -1 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0 | 0  | 0  | 0 | 1 | X12 | = | 2.07246 |     |

Subject 1, Task 4, model solution

| Time  | X1    | X2    | X3    | X4    | X5     | X6    | X7    | X8    | X9    | X10  | X11   | X12  |
|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|------|-------|------|
| 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00   | 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 |
| 0.00  | 0.18  | -0.16 | 0.09  | -0.07 | 64.50  | -0.39 | -0.17 | -0.29 | -1.45 | 0.00 | -3.52 | 2.07 |
| 1.00  | 0.11  | 0.09  | -0.22 | 0.42  | 78.50  | -0.17 | 0.14  | 0.10  | 0.52  | 0.00 | -1.56 | 2.07 |
| 2.00  | 0.60  | -0.22 | -0.16 | 0.54  | 82.00  | 0.14  | 0.32  | 0.37  | 1.86  | 0.00 | -0.21 | 2.07 |
| 3.00  | 0.45  | -0.16 | -0.13 | 0.42  | 78.50  | 0.32  | 0.32  | 0.42  | 2.11  | 0.00 | 0.03  | 2.07 |
| 4.00  | 0.95  | -0.13 | -0.59 | 1.41  | 107.00 | 0.32  | 0.81  | 0.93  | 4.66  | 0.00 | 2.59  | 2.07 |
| 5.00  | 1.53  | -0.59 | -0.37 | 1.31  | 104.00 | 0.81  | 0.93  | 1.19  | 5.98  | 0.00 | 3.91  | 2.07 |
| 6.00  | 1.23  | -0.37 | -0.45 | 1.31  | 104.00 | 0.93  | 0.97  | 1.27  | 6.37  | 0.00 | 4.30  | 2.07 |
| 7.00  | 1.34  | -0.45 | -0.42 | 1.31  | 104.00 | 0.97  | 0.99  | 1.29  | 6.51  | 0.00 | 4.44  | 2.07 |
| 8.00  | 1.35  | -0.42 | -0.47 | 1.40  | 106.50 | 0.99  | 1.04  | 1.35  | 6.79  | 0.00 | 4.72  | 2.07 |
| 9.00  | 1.09  | -0.47 | -0.19 | 0.80  | 89.50  | 1.04  | 0.76  | 1.08  | 5.42  | 0.00 | 3.35  | 2.07 |
| 10.00 | 0.49  | -0.19 | -0.12 | 0.42  | 78.50  | 0.76  | 0.48  | 0.71  | 3.55  | 0.00 | 1.48  | 2.07 |
| 11.00 | 0.39  | -0.12 | -0.14 | 0.40  | 78.00  | 0.48  | 0.37  | 0.51  | 2.58  | 0.00 | 0.51  | 2.07 |
| 12.00 | 0.90  | -0.14 | -0.53 | 1.29  | 103.50 | 0.37  | 0.76  | 0.90  | 4.50  | 0.00 | 2.43  | 2.07 |
| 13.00 | 1.49  | -0.53 | -0.43 | 1.38  | 106.00 | 0.76  | 0.95  | 1.20  | 6.02  | 0.00 | 3.95  | 2.07 |
| 14.00 | 1.27  | -0.43 | -0.41 | 1.26  | 102.50 | 0.95  | 0.95  | 1.25  | 6.30  | 0.00 | 4.23  | 2.07 |
| 15.00 | 1.28  | -0.41 | -0.44 | 1.31  | 104.00 | 0.95  | 0.98  | 1.28  | 6.45  | 0.00 | 4.38  | 2.07 |
| 16.00 | 1.34  | -0.44 | -0.45 | 1.34  | 105.00 | 0.98  | 1.01  | 1.32  | 6.63  | 0.00 | 4.56  | 2.07 |
| 17.00 | 0.89  | -0.45 | -0.06 | 0.51  | 81.00  | 1.01  | 0.61  | 0.91  | 4.57  | 0.00 | 2.50  | 2.07 |
| 18.00 | 0.35  | -0.06 | -0.19 | 0.47  | 80.00  | 0.61  | 0.45  | 0.63  | 3.18  | 0.00 | 1.11  | 2.07 |
| 19.00 | 0.46  | -0.19 | -0.10 | 0.37  | 77.00  | 0.45  | 0.34  | 0.48  | 2.39  | 0.00 | 0.32  | 2.07 |
| 20.00 | 0.15  | -0.10 | 0.02  | 0.04  | 67.50  | 0.34  | 0.14  | 0.24  | 1.19  | 0.00 | -0.88 | 2.07 |
| 21.00 | 0.10  | 0.02  | -0.11 | 0.23  | 73.00  | 0.14  | 0.16  | 0.21  | 1.03  | 0.00 | -1.04 | 2.07 |
| 22.00 | 0.18  | -0.11 | 0.02  | 0.05  | 68.00  | 0.16  | 0.08  | 0.13  | 0.66  | 0.00 | -1.41 | 2.07 |
| 23.00 | 0.72  | 0.02  | -0.62 | 1.36  | 105.50 | 0.08  | 0.70  | 0.75  | 3.76  | 0.00 | 1.69  | 2.07 |
| 24.00 | 1.65  | -0.62 | -0.43 | 1.45  | 108.00 | 0.70  | 0.96  | 1.19  | 5.98  | 0.00 | 3.91  | 2.07 |
| 25.00 | 1.43  | -0.43 | -0.55 | 1.55  | 111.00 | 0.96  | 1.10  | 1.41  | 7.10  | 0.00 | 5.03  | 2.07 |
| 26.00 | 1.57  | -0.55 | -0.48 | 1.50  | 109.50 | 1.10  | 1.13  | 1.48  | 7.43  | 0.00 | 5.36  | 2.07 |
| 27.00 | 1.45  | -0.48 | -0.48 | 1.45  | 108.00 | 1.13  | 1.11  | 1.47  | 7.38  | 0.00 | 5.31  | 2.07 |
| 28.00 | 0.89  | -0.48 | -0.01 | 0.42  | 78.50  | 1.11  | 0.60  | 0.93  | 4.68  | 0.00 | 2.61  | 2.07 |
| 29.00 | -0.09 | -0.01 | 0.09  | -0.19 | 61.00  | 0.60  | 0.12  | 0.29  | 1.46  | 0.00 | -0.61 | 2.07 |
| 30.00 | -0.10 | 0.09  | -0.05 | 0.04  | 67.50  | 0.12  | 0.06  | 0.10  | 0.48  | 0.00 | -1.59 | 2.07 |
| 31.00 | 0.41  | -0.05 | -0.27 | 0.63  | 84.50  | 0.06  | 0.33  | 0.36  | 1.81  | 0.00 | -0.26 | 2.07 |
| 32.00 | 0.78  | -0.27 | -0.24 | 0.75  | 88.00  | 0.33  | 0.49  | 0.60  | 3.00  | 0.00 | 0.93  | 2.07 |
| 33.00 | 0.79  | -0.24 | -0.29 | 0.84  | 90.50  | 0.49  | 0.58  | 0.74  | 3.73  | 0.00 | 1.66  | 2.07 |
| 34.00 | 0.81  | -0.29 | -0.23 | 0.75  | 88.00  | 0.58  | 0.58  | 0.76  | 3.82  | 0.00 | 1.75  | 2.07 |
| 35.00 | 0.75  | -0.23 | -0.27 | 0.79  | 89.00  | 0.58  | 0.59  | 0.77  | 3.89  | 0.00 | 1.81  | 2.07 |
| 36.00 | 0.51  | -0.27 | -0.02 | 0.26  | 74.00  | 0.59  | 0.34  | 0.51  | 2.59  | 0.00 | 0.52  | 2.07 |
| 37.00 | 0.15  | -0.02 | -0.10 | 0.23  | 73.00  | 0.34  | 0.23  | 0.33  | 1.68  | 0.00 | -0.39 | 2.07 |
| 38.00 | 0.27  | -0.10 | -0.08 | 0.25  | 73.50  | 0.23  | 0.20  | 0.27  | 1.38  | 0.00 | -0.69 | 2.07 |

Subject 2, Task 4, Trial 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 64                  | 0.8600               | 0.3780               | 4.2699          | 1.6140          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 65                  | 0.8400               | 0.3860               | 4.2805          | 1.6523          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 65                  | 0.8600               | 0.3820               | 4.2752          | 1.6331          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 64                  | 0.8500               | 0.3140               | 4.1846          | 1.3140          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 62                  | 0.8600               | 0.2730               | 4.1299          | 1.1275          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 63                  | 0.8700               | 0.3220               | 4.1952          | 1.3509          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 75                  | 0.8600               | 0.7240               | 4.7311          | 3.4253          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 91                  | 0.8000               | 0.9220               | 4.9950          | 4.6054          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 91                  | 0.7500               | 1.3590               | 5.5775          | 7.5799          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 92                  | 0.7500               | 1.4180               | 5.6562          | 8.0205          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 89                  | 0.7600               | 1.5050               | 5.7722          | 8.6871          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 92                  | 0.8200               | 1.3880               | 5.6162          | 7.7953          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 89                  | 0.7800               | 1.3820               | 5.6082          | 7.7505          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 90                  | 0.8200               | 1.4270               | 5.6682          | 8.0885          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 91                  | 0.8100               | 1.4300               | 5.6722          | 8.1112          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 92                  | 0.8500               | 1.5600               | 5.8455          | 9.1189          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 96                  | 0.8400               | 1.1850               | 5.3456          | 6.3345          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 65                  | 0.9100               | 0.7740               | 4.7977          | 3.7135          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 90                  | 0.9600               | 0.4830               | 4.4098          | 2.1300          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 58                  | 0.9500               | 0.3900               | 4.2859          | 1.6715          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 62                  | 0.9300               | 0.3860               | 4.2805          | 1.6523          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 64                  | 0.9300               | 0.4340               | 4.3445          | 1.8855          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 75                  | 0.9300               | 0.8570               | 4.9084          | 4.2065          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 91                  | 0.8800               | 1.0350               | 5.1457          | 5.3258          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 93                  | 0.8700               | 1.2680               | 5.4562          | 6.9185          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 87                  | 0.8900               | 1.3260               | 5.5336          | 7.3375          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 87                  | 0.8900               | 1.2390               | 5.4176          | 6.7124          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 88                  | 0.8900               | 1.3020               | 5.5016          | 7.1630          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 88                  | 0.8800               | 1.1920               | 5.3549          | 6.3831          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 87                  | 0.8600               | 1.3010               | 5.5002          | 7.1558          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 88                  | 0.8600               | 1.2400               | 5.4189          | 6.7195          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 86                  | 0.9000               | 1.3410               | 5.5536          | 7.4473          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 80                  | 0.8900               | 1.0680               | 5.1896          | 5.5425          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 68                  | 0.9400               | 0.7450               | 4.7591          | 3.5455          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 63                  | 1.0000               | 0.5850               | 4.5458          | 2.6593          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 62                  | 1.0100               | 0.3090               | 4.1779          | 1.2910          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 66                  | 0.9400               | 0.3780               | 4.2699          | 1.6140          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 68                  | 0.9300               | 0.4210               | 4.3272          | 1.8217          | 0.0000 |



Subject 2, Task 4, Trial 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 61                  | 0.9000                                        | 0.4210                           | 4.9657          | 2.0906                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 71                  | 0.9000                                        | 0.4210                           | 4.9657          | 2.0906                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 61                  | 0.8900                                        | 0.3160                           | 4.9524          | 1.5649                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 62                  | 0.8900                                        | 0.3160                           | 4.9524          | 1.5649                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 68                  | 0.9100                                        | 0.3250                           | 4.9790          | 1.6182                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 68                  | 0.9100                                        | 0.3250                           | 4.9790          | 1.6182                      | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 77                  | 0.8700                                        | 0.8140                           | 4.9257          | 4.0095                      | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 85                  | 0.8700                                        | 0.8140                           | 4.9257          | 4.0095                      | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 77                  | 0.8100                                        | 0.9970                           | 4.8457          | 4.8312                      | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 78                  | 0.8100                                        | 0.9970                           | 4.8457          | 4.8312                      | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 80                  | 0.7900                                        | 0.9970                           | 4.8191          | 4.8046                      | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 78                  | 0.7900                                        | 0.9970                           | 4.8191          | 4.8046                      | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 80                  | 0.8300                                        | 1.0250                           | 4.8724          | 4.9942                      | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 79                  | 0.8300                                        | 1.0250                           | 4.8724          | 4.9942                      | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 79                  | 0.8500                                        | 1.0030                           | 4.8991          | 4.9137                      | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 78                  | 0.8500                                        | 1.0030                           | 4.8991          | 4.9137                      | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 78                  | 0.8100                                        | 0.8290                           | 4.8457          | 4.0171                      | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 63                  | 0.8100                                        | 0.8290                           | 4.8457          | 4.0171                      | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 59                  | 0.8700                                        | 0.3760                           | 4.9257          | 1.8521                      | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 64                  | 0.8700                                        | 0.3760                           | 4.9257          | 1.8521                      | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 58                  | 0.8900                                        | 0.3490                           | 4.9524          | 1.7284                      | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 59                  | 0.8900                                        | 0.3490                           | 4.9524          | 1.7284                      | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 75                  | 0.8600                                        | 1.0230                           | 4.9124          | 5.0254                      | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 96                  | 0.8600                                        | 1.0230                           | 4.9124          | 5.0254                      | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 99                  | 0.8200                                        | 1.5740                           | 4.8591          | 7.6482                      | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 100                 | 0.8200                                        | 1.5740                           | 4.8591          | 7.6482                      | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 98                  | 0.8400                                        | 1.6760                           | 4.8857          | 8.1885                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 96                  | 0.8400                                        | 1.6760                           | 4.8857          | 8.1885                      | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 95                  | 0.8600                                        | 1.5980                           | 4.9124          | 7.8500                      | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 98                  | 0.8600                                        | 1.5980                           | 4.9124          | 7.8500                      | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 96                  | 0.8700                                        | 1.5920                           | 4.9257          | 7.8417                      | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 96                  | 0.8700                                        | 1.5920                           | 4.9257          | 7.8417                      | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 87                  | 0.8600                                        | 1.3930                           | 4.9124          | 6.8429                      | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 68                  | 0.8600                                        | 1.3930                           | 4.9124          | 6.8429                      | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 58                  | 1.0000                                        | 0.5330                           | 5.0990          | 2.7178                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 57                  | 1.0000                                        | 0.5330                           | 5.0990          | 2.7178                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 60                  | 0.9600                                        | 0.4170                           | 5.0457          | 2.1040                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 60                  | 0.9600                                        | 0.4170                           | 5.0457          | 2.1040                      | 0.0000 |

Subject 2, Test 4

|               |                                                     |                                          |
|---------------|-----------------------------------------------------|------------------------------------------|
| Equation Type | Equation                                            | Equation Parameters                      |
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | $D = 0.33 \quad \alpha = 0.60$           |
| i/t           |                                                     |                                          |
| balance       | $X1 + X2 = X3 + X4$                                 |                                          |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | $\text{Coef} = 0.0293 \quad C = -1.9650$ |
| exogenous     |                                                     |                                          |
| i/t           |                                                     |                                          |
| balance       | $X4 + X6 = X7 + X8$                                 |                                          |
| regression    | $X8 = 1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$  | $D = 0.76 \quad \alpha = 0.21$           |
| gain          | $X9 = Y \cdot X8$                                   | $Y = 4.9483$                             |
| balance       | $X9 = X10 + X11 + X12$                              |                                          |
| regression    | $X10 = \text{Eff} \cdot X11$                        | $\text{Eff} = 0.0000$                    |
| exogenous     | $X12 = \text{RM}$                                   | $\text{RM} = 1.8051$                     |

|   |        |        |    |       |        |        |       |    |    |   |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|---|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X4  | = | 1.965   |     |
| 0 | 0      | 0      | 0  | 1     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X5  | = | 64.5    | ex  |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0 | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0.2763 | 1.0395 | -1    | 0  | 0  | 0 | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | -4.95 | 1  | 0  | 0 | 0 | 0 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1 | 1 | 1 | X10 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 1 | X12 | = | 1.80506 |     |

Subject 2, Task 4, model solution

| Time  | X1    | X2    | X3    | X4    | X5    | X6    | X7    | X8    | X9    | X10  | X11   | X12  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|-------|------|
| 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 |
| 0.00  | 0.17  | -0.16 | 0.09  | -0.08 | 64.50 | -0.39 | -0.18 | -0.29 | -1.44 | 0.00 | -3.25 | 1.81 |
| 1.00  | -0.17 | 0.09  | 0.00  | -0.08 | 64.50 | -0.18 | -0.10 | -0.15 | -0.75 | 0.00 | -2.56 | 1.81 |
| 2.00  | -0.04 | 0.00  | 0.03  | -0.08 | 64.50 | -0.10 | -0.07 | -0.10 | -0.51 | 0.00 | -2.31 | 1.81 |
| 3.00  | -0.12 | 0.03  | 0.05  | -0.13 | 62.50 | -0.07 | -0.09 | -0.11 | -0.57 | 0.00 | -2.37 | 1.81 |
| 4.00  | 0.19  | 0.05  | -0.23 | 0.47  | 83.00 | -0.09 | 0.20  | 0.18  | 0.89  | 0.00 | -0.92 | 1.81 |
| 5.00  | 0.71  | -0.23 | -0.24 | 0.72  | 91.50 | 0.20  | 0.42  | 0.49  | 2.43  | 0.00 | 0.63  | 1.81 |
| 6.00  | 0.70  | -0.24 | -0.22 | 0.69  | 90.50 | 0.42  | 0.49  | 0.62  | 3.08  | 0.00 | 1.27  | 1.81 |
| 7.00  | 0.66  | -0.22 | -0.22 | 0.66  | 89.50 | 0.49  | 0.49  | 0.65  | 3.21  | 0.00 | 1.40  | 1.81 |
| 8.00  | 0.69  | -0.22 | -0.24 | 0.72  | 91.50 | 0.49  | 0.53  | 0.68  | 3.39  | 0.00 | 1.58  | 1.81 |
| 9.00  | 0.55  | -0.24 | -0.09 | 0.39  | 80.50 | 0.53  | 0.38  | 0.54  | 2.67  | 0.00 | 0.87  | 1.81 |
| 10.00 | 0.23  | -0.09 | -0.06 | 0.20  | 74.00 | 0.38  | 0.23  | 0.35  | 1.73  | 0.00 | -0.08 | 1.81 |
| 11.00 | 0.02  | -0.06 | 0.08  | -0.12 | 63.00 | 0.23  | 0.02  | 0.09  | 0.45  | 0.00 | -1.36 | 1.81 |
| 12.00 | 0.15  | 0.08  | -0.24 | 0.47  | 83.00 | 0.02  | 0.24  | 0.25  | 1.26  | 0.00 | -0.55 | 1.81 |
| 13.00 | 0.70  | -0.24 | -0.22 | 0.67  | 90.00 | 0.24  | 0.41  | 0.50  | 2.45  | 0.00 | 0.65  | 1.81 |
| 14.00 | 0.62  | -0.22 | -0.19 | 0.60  | 87.50 | 0.41  | 0.44  | 0.57  | 2.83  | 0.00 | 1.03  | 1.81 |
| 15.00 | 0.59  | -0.19 | -0.20 | 0.60  | 87.50 | 0.44  | 0.45  | 0.59  | 2.92  | 0.00 | 1.11  | 1.81 |
| 16.00 | 0.59  | -0.20 | -0.19 | 0.58  | 87.00 | 0.45  | 0.45  | 0.59  | 2.91  | 0.00 | 1.10  | 1.81 |
| 17.00 | 0.37  | -0.19 | -0.02 | 0.20  | 74.00 | 0.45  | 0.26  | 0.39  | 1.94  | 0.00 | 0.13  | 1.81 |
| 18.00 | -0.04 | -0.02 | 0.07  | -0.13 | 62.50 | 0.26  | 0.03  | 0.10  | 0.49  | 0.00 | -1.32 | 1.81 |
| 19.00 | -0.09 | 0.07  | -0.02 | 0.00  | 67.00 | 0.03  | 0.01  | 0.02  | 0.08  | 0.00 | -1.73 | 1.81 |
| 20.00 | 0.02  | -0.02 | 0.02  | -0.03 | 66.00 | 0.01  | -0.01 | -0.01 | -0.05 | 0.00 | -1.86 | 1.81 |
| 21.00 | -0.12 | 0.02  | 0.07  | -0.16 | 61.50 | -0.01 | -0.08 | -0.09 | -0.45 | 0.00 | -2.26 | 1.81 |
| 22.00 | -0.07 | 0.07  | -0.04 | 0.03  | 68.00 | -0.08 | -0.02 | -0.04 | -0.20 | 0.00 | -2.01 | 1.81 |
| 23.00 | 0.27  | -0.04 | -0.17 | 0.41  | 81.00 | -0.02 | 0.19  | 0.20  | 0.98  | 0.00 | -0.83 | 1.81 |
| 24.00 | 0.40  | -0.17 | -0.07 | 0.31  | 77.50 | 0.19  | 0.22  | 0.28  | 1.39  | 0.00 | -0.41 | 1.81 |
| 25.00 | 0.29  | -0.07 | -0.13 | 0.35  | 79.00 | 0.22  | 0.25  | 0.32  | 1.58  | 0.00 | -0.22 | 1.81 |
| 26.00 | 0.38  | -0.13 | -0.12 | 0.36  | 79.50 | 0.25  | 0.27  | 0.35  | 1.71  | 0.00 | -0.09 | 1.81 |
| 27.00 | 0.34  | -0.12 | -0.11 | 0.34  | 78.50 | 0.27  | 0.26  | 0.34  | 1.70  | 0.00 | -0.11 | 1.81 |
| 28.00 | 0.20  | -0.11 | -0.01 | 0.10  | 70.50 | 0.26  | 0.14  | 0.22  | 1.08  | 0.00 | -0.72 | 1.81 |
| 29.00 | -0.08 | -0.01 | 0.08  | -0.16 | 61.50 | 0.14  | -0.03 | 0.01  | 0.04  | 0.00 | -1.77 | 1.81 |
| 30.00 | -0.24 | 0.08  | 0.09  | -0.25 | 58.50 | -0.03 | -0.13 | -0.15 | -0.73 | 0.00 | -2.53 | 1.81 |
| 31.00 | 0.18  | 0.09  | -0.28 | 0.54  | 85.50 | -0.13 | 0.22  | 0.19  | 0.94  | 0.00 | -0.87 | 1.81 |
| 32.00 | 0.90  | -0.28 | -0.33 | 0.95  | 99.50 | 0.22  | 0.54  | 0.62  | 3.09  | 0.00 | 1.29  | 1.81 |
| 33.00 | 0.93  | -0.33 | -0.28 | 0.88  | 97.00 | 0.54  | 0.62  | 0.80  | 3.95  | 0.00 | 2.14  | 1.81 |
| 34.00 | 0.85  | -0.28 | -0.29 | 0.86  | 96.50 | 0.62  | 0.64  | 0.84  | 4.16  | 0.00 | 2.36  | 1.81 |
| 35.00 | 0.86  | -0.29 | -0.28 | 0.85  | 96.00 | 0.64  | 0.64  | 0.85  | 4.19  | 0.00 | 2.39  | 1.81 |
| 36.00 | 0.55  | -0.28 | -0.04 | 0.31  | 77.50 | 0.64  | 0.38  | 0.57  | 2.83  | 0.00 | 1.02  | 1.81 |
| 37.00 | -0.10 | -0.04 | 0.14  | -0.28 | 57.50 | 0.38  | 0.00  | 0.10  | 0.50  | 0.00 | -1.30 | 1.81 |
| 38.00 | -0.31 | 0.14  | 0.04  | -0.21 | 60.00 | 0.00  | -0.10 | -0.11 | -0.53 | 0.00 | -2.34 | 1.81 |



Subject 3, Task 4, Trial 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 64                  | 0.7200               | 0.3490               | 4.2312          | 1.4767          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 68                  | 0.7100               | 0.2120               | 4.0486          | 0.8583          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 70                  | 0.6800               | 0.1550               | 3.9726          | 0.6158          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 65                  | 0.7100               | 0.2160               | 4.0539          | 0.8756          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 67                  | 0.7100               | 0.1720               | 3.9953          | 0.6872          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 64                  | 0.7600               | 0.3780               | 4.2699          | 1.6140          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 86                  | 0.7900               | 0.4360               | 4.3472          | 1.8954          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 94                  | 0.7700               | 0.6140               | 4.5845          | 2.8149          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 98                  | 0.7100               | 0.9020               | 4.9684          | 4.4815          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 98                  | 0.7100               | 0.9860               | 5.0803          | 5.0092          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 97                  | 0.7200               | 0.9410               | 5.0204          | 4.7242          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 95                  | 0.7400               | 0.8990               | 4.9644          | 4.4630          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 97                  | 0.7400               | 0.9490               | 5.0310          | 4.7744          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 95                  | 0.7600               | 0.9270               | 5.0017          | 4.6366          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 97                  | 0.7600               | 0.9540               | 5.0377          | 4.8059          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 97                  | 0.7700               | 0.9350               | 5.0124          | 4.6866          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 80                  | 0.7900               | 0.6990               | 4.6978          | 3.2837          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 78                  | 0.7800               | 0.4520               | 4.3685          | 1.9746          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 70                  | 0.8300               | 0.3390               | 4.2179          | 1.4299          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 68                  | 0.8400               | 0.2820               | 4.1419          | 1.1680          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 71                  | 0.9400               | 0.2970               | 4.1619          | 1.2361          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 67                  | 0.8200               | 0.1980               | 4.0299          | 0.7979          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 93                  | 0.8600               | 0.5740               | 4.5311          | 2.6009          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 111                 | 0.8800               | 0.8110               | 4.8471          | 3.9310          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 110                 | 0.7800               | 1.0940               | 5.2243          | 5.7154          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 111                 | 0.8000               | 1.1480               | 5.2963          | 6.0801          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 114                 | 0.8000               | 1.1030               | 5.2363          | 5.7756          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 117                 | 0.8300               | 1.2730               | 5.4629          | 6.9543          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 110                 | 0.8300               | 1.2460               | 5.4269          | 6.7619          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 113                 | 0.8100               | 1.2080               | 5.3763          | 6.4945          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 110                 | 0.8200               | 1.1940               | 5.3576          | 6.3970          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 112                 | 0.8100               | 1.1480               | 5.2963          | 6.0801          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 83                  | 0.8100               | 0.9660               | 5.0537          | 4.8819          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 76                  | 0.8100               | 0.6680               | 4.6564          | 3.1105          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 68                  | 0.8600               | 0.4060               | 4.3072          | 1.7487          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 64                  | 0.8900               | 0.2270               | 4.0686          | 0.9236          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 67                  | 0.8700               | 0.1560               | 3.9739          | 0.6199          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 68                  | 0.8200               | 0.1380               | 3.9500          | 0.5451          | 0.0000 |



Subject 3, Task 4, Trial 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 68                  | 0.8000                                        | 0.2150                           | 4.8324          | 1.0390                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 67                  | 0.7800                                        | 0.1130                           | 4.8057          | 0.5430                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 67                  | 0.7500                                        | 0.1110                           | 4.7658          | 0.5290                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 67                  | 0.7900                                        | 0.1380                           | 4.8191          | 0.6650                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 65                  | 0.7800                                        | 0.1450                           | 4.8057          | 0.6968                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 70                  | 0.8500                                        | 0.2760                           | 4.8991          | 1.3521                      | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 85                  | 0.9000                                        | 0.5660                           | 4.9657          | 2.8106                      | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 105                 | 0.8300                                        | 0.6900                           | 4.8724          | 3.3619                      | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 107                 | 0.7800                                        | 0.8960                           | 4.8057          | 4.3059                      | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 106                 | 0.7700                                        | 0.9050                           | 4.7924          | 4.3371                      | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 102                 | 0.7600                                        | 0.9860                           | 4.7791          | 4.7122                      | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 96                  | 0.7900                                        | 0.8880                           | 4.8191          | 4.2793                      | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 99                  | 0.7700                                        | 0.9050                           | 4.7924          | 4.3371                      | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 98                  | 0.7700                                        | 0.9060                           | 4.7924          | 4.3419                      | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 95                  | 0.7800                                        | 0.8990                           | 4.8057          | 4.3204                      | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 97                  | 0.7900                                        | 0.8530                           | 4.8191          | 4.1107                      | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 83                  | 0.8000                                        | 0.7400                           | 4.8324          | 3.5760                      | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 75                  | 0.7900                                        | 0.5240                           | 4.8191          | 2.5252                      | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 68                  | 0.7800                                        | 0.2620                           | 4.8057          | 1.2591                      | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 70                  | 0.7900                                        | 0.1890                           | 4.8191          | 0.9108                      | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 69                  | 0.7500                                        | 0.1580                           | 4.7658          | 0.7530                      | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 76                  | 0.8100                                        | 0.3400                           | 4.8457          | 1.6475                      | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 88                  | 0.8300                                        | 0.4920                           | 4.8724          | 2.3972                      | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 91                  | 0.8100                                        | 0.4690                           | 4.8457          | 2.2726                      | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 94                  | 0.7600                                        | 0.6530                           | 4.7791          | 3.1207                      | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 95                  | 0.7500                                        | 0.7640                           | 4.7658          | 3.6410                      | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 88                  | 0.7500                                        | 0.7930                           | 4.7658          | 3.7792                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 87                  | 0.7600                                        | 0.7290                           | 4.7791          | 3.4839                      | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 96                  | 0.7600                                        | 0.7990                           | 4.7791          | 3.8185                      | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 90                  | 0.7700                                        | 0.7640                           | 4.7924          | 3.6614                      | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 95                  | 0.7800                                        | 0.7360                           | 4.8057          | 3.5370                      | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 94                  | 0.7900                                        | 0.7000                           | 4.8191          | 3.3733                      | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 81                  | 0.7700                                        | 0.6020                           | 4.7924          | 2.8850                      | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 77                  | 0.7700                                        | 0.3080                           | 4.7924          | 1.4761                      | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 77                  | 0.7900                                        | 0.2770                           | 4.8191          | 1.3349                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 74                  | 0.8200                                        | 0.2260                           | 4.8591          | 1.0981                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 66                  | 0.7900                                        | 0.2910                           | 4.8191          | 1.4023                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 69                  | 0.7500                                        | 0.1970                           | 4.7658          | 0.9389                      | 0.0000 |

## Subject 3, Test 4

| Equation Type | Equation                                            | Equation Parameters |        |       |         |
|---------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.33   | alfa= | 0.60    |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0305 | C =   | -1.9627 |
| exogenous     |                                                     |                     |        |       |         |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| regression    | $X8 = 1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$  | D=                  | 0.76   | alfa= | 0.21    |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 4.7397 |       |         |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0000 |       |         |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 1.0354 |       |         |

|   |        |        |    |       |        |        |       |    |    |   |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|-------|----|----|---|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.031 | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X4  | = | 1.9627  |     |
| 0 | 0      | 0      | 0  | 1     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X5  | = | 64.5    | ex  |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0     | 0  | 0  | 0 | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1    | 0  | 0  | 0 | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0.2763 | 1.0395 | -1    | 0  | 0  | 0 | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | -4.74 | 1  | 0  | 0 | 0 | 0 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | -1 | 1  | 1 | 1 | 1 | X10 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | -1 | 0 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0     | 0  | 0  | 0 | 0 | 1 | X12 | = | 1.0354  |     |

Subject 3, Task 4, model solution

| Time  | X1    | X2    | X3    | X4   | X5     | X6    | X7    | X8    | X9    | X10  | X11   | X12  |
|-------|-------|-------|-------|------|--------|-------|-------|-------|-------|------|-------|------|
| 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 |
| 0.00  | 0.22  | -0.16 | 0.06  | 0.00 | 64.50  | -0.39 | -0.14 | -0.25 | -1.19 | 0.00 | -2.23 | 1.04 |
| 1.00  | -0.05 | 0.06  | -0.04 | 0.05 | 66.00  | -0.14 | -0.02 | -0.06 | -0.30 | 0.00 | -1.33 | 1.04 |
| 2.00  | 0.11  | -0.04 | -0.03 | 0.10 | 67.50  | -0.02 | 0.04  | 0.03  | 0.16  | 0.00 | -0.88 | 1.04 |
| 3.00  | 0.06  | -0.03 | -0.01 | 0.04 | 65.50  | 0.04  | 0.03  | 0.04  | 0.20  | 0.00 | -0.83 | 1.04 |
| 4.00  | 0.44  | -0.01 | -0.35 | 0.78 | 90.00  | 0.03  | 0.39  | 0.42  | 1.98  | 0.00 | 0.95  | 1.04 |
| 5.00  | 1.04  | -0.35 | -0.33 | 1.03 | 98.00  | 0.39  | 0.64  | 0.78  | 3.69  | 0.00 | 2.65  | 1.04 |
| 6.00  | 0.99  | -0.33 | -0.31 | 0.97 | 96.00  | 0.64  | 0.70  | 0.91  | 4.30  | 0.00 | 3.26  | 1.04 |
| 7.00  | 0.96  | -0.31 | -0.32 | 0.97 | 96.00  | 0.70  | 0.72  | 0.94  | 4.48  | 0.00 | 3.44  | 1.04 |
| 8.00  | 0.98  | -0.32 | -0.33 | 1.00 | 97.00  | 0.72  | 0.74  | 0.97  | 4.61  | 0.00 | 3.58  | 1.04 |
| 9.00  | 0.70  | -0.33 | -0.08 | 0.45 | 79.00  | 0.74  | 0.48  | 0.71  | 3.36  | 0.00 | 2.32  | 1.04 |
| 10.00 | 0.19  | -0.08 | -0.03 | 0.14 | 69.00  | 0.48  | 0.24  | 0.38  | 1.82  | 0.00 | 0.78  | 1.04 |
| 11.00 | 0.13  | -0.03 | -0.05 | 0.14 | 69.00  | 0.24  | 0.16  | 0.23  | 1.08  | 0.00 | 0.04  | 1.04 |
| 12.00 | 0.70  | -0.05 | -0.50 | 1.15 | 102.00 | 0.16  | 0.62  | 0.69  | 3.25  | 0.00 | 2.21  | 1.04 |
| 13.00 | 1.46  | -0.50 | -0.45 | 1.41 | 110.50 | 0.62  | 0.91  | 1.12  | 5.29  | 0.00 | 4.25  | 1.04 |
| 14.00 | 1.47  | -0.45 | -0.54 | 1.56 | 115.50 | 0.91  | 1.09  | 1.38  | 6.55  | 0.00 | 5.51  | 1.04 |
| 15.00 | 1.53  | -0.54 | -0.45 | 1.44 | 111.50 | 1.09  | 1.09  | 1.43  | 6.80  | 0.00 | 5.76  | 1.04 |
| 16.00 | 1.40  | -0.45 | -0.48 | 1.42 | 111.00 | 1.09  | 1.08  | 1.43  | 6.77  | 0.00 | 5.74  | 1.04 |
| 17.00 | 0.91  | -0.48 | -0.03 | 0.46 | 79.50  | 1.08  | 0.61  | 0.94  | 4.43  | 0.00 | 3.40  | 1.04 |
| 18.00 | 0.07  | -0.03 | -0.01 | 0.05 | 66.00  | 0.61  | 0.24  | 0.42  | 1.99  | 0.00 | 0.96  | 1.04 |
| 19.00 | 0.07  | -0.01 | -0.04 | 0.10 | 67.50  | 0.24  | 0.13  | 0.20  | 0.97  | 0.00 | -0.06 | 1.04 |
| 20.00 | 0.11  | -0.04 | -0.03 | 0.10 | 67.50  | 0.13  | 0.09  | 0.13  | 0.64  | 0.00 | -0.40 | 1.04 |
| 21.00 | 0.08  | -0.03 | -0.03 | 0.08 | 67.00  | 0.09  | 0.07  | 0.10  | 0.48  | 0.00 | -0.55 | 1.04 |
| 22.00 | 0.09  | -0.03 | -0.03 | 0.10 | 67.50  | 0.07  | 0.07  | 0.10  | 0.46  | 0.00 | -0.58 | 1.04 |
| 23.00 | 0.56  | -0.03 | -0.41 | 0.93 | 95.00  | 0.07  | 0.48  | 0.52  | 2.48  | 0.00 | 1.45  | 1.04 |
| 24.00 | 1.27  | -0.41 | -0.43 | 1.29 | 106.50 | 0.48  | 0.80  | 0.97  | 4.59  | 0.00 | 3.55  | 1.04 |
| 25.00 | 1.17  | -0.43 | -0.32 | 1.06 | 99.00  | 0.80  | 0.80  | 1.06  | 5.01  | 0.00 | 3.97  | 1.04 |
| 26.00 | 1.01  | -0.32 | -0.35 | 1.04 | 98.50  | 0.80  | 0.80  | 1.05  | 4.97  | 0.00 | 3.94  | 1.04 |
| 27.00 | 1.01  | -0.35 | -0.31 | 0.97 | 96.00  | 0.80  | 0.76  | 1.01  | 4.76  | 0.00 | 3.73  | 1.04 |
| 28.00 | 0.66  | -0.31 | -0.09 | 0.45 | 79.00  | 0.76  | 0.49  | 0.72  | 3.39  | 0.00 | 2.35  | 1.04 |
| 29.00 | 0.20  | -0.09 | -0.03 | 0.14 | 69.00  | 0.49  | 0.24  | 0.39  | 1.83  | 0.00 | 0.80  | 1.04 |
| 30.00 | 0.18  | -0.03 | -0.10 | 0.25 | 72.50  | 0.24  | 0.21  | 0.28  | 1.34  | 0.00 | 0.31  | 1.04 |
| 31.00 | 0.56  | -0.10 | -0.31 | 0.77 | 89.50  | 0.21  | 0.45  | 0.53  | 2.49  | 0.00 | 1.45  | 1.04 |
| 32.00 | 0.93  | -0.31 | -0.30 | 0.92 | 94.50  | 0.45  | 0.61  | 0.76  | 3.60  | 0.00 | 2.56  | 1.04 |
| 33.00 | 0.80  | -0.30 | -0.21 | 0.71 | 87.50  | 0.61  | 0.56  | 0.75  | 3.57  | 0.00 | 2.54  | 1.04 |
| 34.00 | 0.76  | -0.21 | -0.32 | 0.87 | 93.00  | 0.56  | 0.63  | 0.81  | 3.83  | 0.00 | 2.80  | 1.04 |
| 35.00 | 0.94  | -0.32 | -0.30 | 0.92 | 94.50  | 0.63  | 0.67  | 0.87  | 4.14  | 0.00 | 3.11  | 1.04 |
| 36.00 | 0.65  | -0.30 | -0.09 | 0.45 | 79.00  | 0.67  | 0.46  | 0.66  | 3.14  | 0.00 | 2.10  | 1.04 |
| 37.00 | 0.31  | -0.09 | -0.12 | 0.34 | 75.50  | 0.46  | 0.33  | 0.47  | 2.22  | 0.00 | 1.19  | 1.04 |
| 38.00 | 0.22  | -0.12 | 0.00  | 0.10 | 67.50  | 0.33  | 0.16  | 0.26  | 1.24  | 0.00 | 0.20  | 1.04 |



Subject 4, Task 4, Trial 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 92                  | 0.8200                                        | 0.4600                           | 4.3792          | 2.0144                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 84                  | 0.8400                                        | 0.3250                           | 4.1992          | 1.3647                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 87                  | 0.8700                                        | 0.3420                           | 4.2219          | 1.4439                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 86                  | 0.8300                                        | 0.3350                           | 4.2126          | 1.4112                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 83                  | 0.8600                                        | 0.3030                           | 4.1699          | 1.2635                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 84                  | 0.8200                                        | 0.4660                           | 4.3872          | 2.0444                      | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 107                 | 0.8100                                        | 0.9390                           | 5.0177          | 4.7116                      | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 125                 | 0.8100                                        | 1.6040                           | 5.9041          | 9.4702                      | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 129                 | 0.8300                                        | 1.0680                           | 5.1896          | 5.5425                      | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 134                 | 0.8500                                        | 2.1240                           | 6.5973          | 14.0126                     | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 130                 | 0.8400                                        | 2.1320                           | 6.6080          | 14.0882                     | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 131                 | 0.8600                                        | 2.0940                           | 6.5573          | 13.7310                     | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 122                 | 0.8500                                        | 2.1270                           | 6.6013          | 14.0409                     | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 127                 | 0.8400                                        | 2.2180                           | 6.7226          | 14.9107                     | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 133                 | 0.8400                                        | 2.2170                           | 6.7213          | 14.9010                     | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 130                 | 0.8400                                        | 2.2280                           | 6.7359          | 15.0076                     | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 109                 | 0.9000                                        | 1.7800                           | 6.1387          | 10.9270                     | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 106                 | 0.9400                                        | 1.0280                           | 5.1363          | 5.2801                      | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 101                 | 0.9200                                        | 0.8390                           | 4.8844          | 4.0980                      | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 98                  | 1.0200                                        | 0.6690                           | 4.6578          | 3.1161                      | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 103                 | 0.9500                                        | 0.5770                           | 4.5351          | 2.6168                      | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 95                  | 0.9300                                        | 0.3900                           | 4.2859          | 1.6715                      | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 109                 | 0.8600                                        | 0.7890                           | 4.8177          | 3.8012                      | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 113                 | 0.8900                                        | 1.0350                           | 5.1457          | 5.3258                      | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 113                 | 0.8700                                        | 1.1160                           | 5.2536          | 5.8630                      | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 107                 | 0.8500                                        | 1.2230                           | 5.3963          | 6.5996                      | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 110                 | 0.8600                                        | 1.2280                           | 5.4029          | 6.6348                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 110                 | 0.8700                                        | 1.1690                           | 5.3243          | 6.2241                      | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 110                 | 0.8700                                        | 1.1500                           | 5.2990          | 6.0938                      | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 110                 | 0.8700                                        | 1.1930                           | 5.3563          | 6.3900                      | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 108                 | 0.8400                                        | 1.0990                           | 5.2310          | 5.7488                      | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 110                 | 0.8600                                        | 1.1110                           | 5.2470          | 5.8294                      | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 100                 | 0.9000                                        | 1.0600                           | 5.1790          | 5.4897                      | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 87                  | 0.9800                                        | 0.5430                           | 4.4898          | 2.4380                      | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 89                  | 0.8900                                        | 0.4890                           | 4.4178          | 2.1603                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 93                  | 0.9200                                        | 0.4870                           | 4.4152          | 2.1502                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 93                  | 0.8900                                        | 0.4060                           | 4.3072          | 1.7487                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 92                  | 0.8800                                        | 0.3820                           | 4.2752          | 1.6331                      | 0.0000 |

Subject 4, Task 4, Trial 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 96                  | 0.8700               | 0.4470               | 4.9257          | 2.2018          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 87                  | 0.8600               | 0.4930               | 4.9124          | 2.4218          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 92                  | 0.9000               | 0.3680               | 4.9657          | 1.8274          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 88                  | 0.8300               | 0.3610               | 4.8724          | 1.7589          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 94                  | 0.8500               | 0.4080               | 4.8991          | 1.9988          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 88                  | 0.8500               | 0.3880               | 4.8991          | 1.9008          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 98                  | 0.8300               | 0.7680               | 4.8724          | 3.7420          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 124                 | 0.8400               | 1.4300               | 4.8857          | 6.9866          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 122                 | 0.8200               | 1.7210               | 4.8591          | 8.3624          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 124                 | 0.8200               | 1.7670               | 4.8591          | 8.5860          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 124                 | 0.8200               | 1.8370               | 4.8591          | 8.9261          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 124                 | 0.8400               | 1.7120               | 4.8857          | 8.3644          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 122                 | 0.8300               | 1.7890               | 4.8724          | 8.7167          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 125                 | 0.8200               | 1.8000               | 4.8591          | 8.7463          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 125                 | 0.8400               | 1.7960               | 4.8857          | 8.7748          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 124                 | 0.8500               | 1.7330               | 4.8991          | 8.4901          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 111                 | 0.8500               | 1.4760               | 4.8991          | 7.2310          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 109                 | 0.9600               | 0.8250               | 5.0457          | 4.1627          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 99                  | 0.8700               | 0.6110               | 4.9257          | 3.0096          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 97                  | 0.9000               | 0.5770               | 4.9657          | 2.8652          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 102                 | 0.9500               | 0.4450               | 5.0324          | 2.2394          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 95                  | 0.9000               | 0.3780               | 4.9657          | 1.8770          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 76                  | 0.8700               | 0.6700               | 4.9257          | 3.3002          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 123                 | 0.8700               | 0.9950               | 4.9257          | 4.9011          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 123                 | 0.8400               | 1.4790               | 4.8857          | 7.2260          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 123                 | 0.8600               | 1.6840               | 4.9124          | 8.2724          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 122                 | 0.8800               | 1.6060               | 4.9390          | 7.9321          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 122                 | 0.8800               | 1.5670               | 4.9390          | 7.7395          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 125                 | 0.8700               | 1.5080               | 4.9257          | 7.4280          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 123                 | 0.8500               | 1.5320               | 4.8991          | 7.5053          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 122                 | 0.8600               | 1.5620               | 4.9124          | 7.6731          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 126                 | 0.8600               | 1.5400               | 4.9124          | 7.5651          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 116                 | 0.9000               | 1.3470               | 4.9657          | 6.6888          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 108                 | 0.9600               | 0.8520               | 5.0457          | 4.2989          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 95                  | 0.9200               | 0.5130               | 4.9924          | 2.5611          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 103                 | 0.9600               | 0.5150               | 5.0457          | 2.5985          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 96                  | 0.9500               | 0.3950               | 5.0324          | 1.9878          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 96                  | 0.8700               | 0.3750               | 4.9257          | 1.8471          | 0.0000 |

Subject 4, Test 4

| Equation Type | Equation                                            | Equation Parameters |        |       |         |
|---------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.33   | alfa= | 0.60    |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0343 | C =   | -2.2578 |
| exogenous     |                                                     |                     |        |       |         |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| regression    | $X8 = 1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$  | D=                  | 0.76   | alfa= | 0.21    |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 5.0612 |       |         |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0000 |       |         |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 2.1596 |       |         |

|   |        |        |    |       |        |        |        |    |    |   |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|--------|----|----|---|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.034 | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X4  | = | 2.2578  |     |
| 0 | 0      | 0      | 0  | 1     | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X5  | = | 64.5    | ex  |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0      | 0  | 0  | 0 | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1     | 0  | 0  | 0 | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0.2763 | 1.0395 | -1     | 0  | 0  | 0 | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | -5.061 | 1  | 0  | 0 | 0 | 0 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | -1 | 1  | 1 | 1 | 1 | X10 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | 0  | -1 | 0 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | 0  | 0  | 0 | 0 | 1 | X12 | = | 2.15956 |     |



## Subject 4, Task 4, model solution

| Time  | X1   | X2    | X3    | X4    | X5     | X6    | X7    | X8    | X9    | X10  | X11   | X12  |
|-------|------|-------|-------|-------|--------|-------|-------|-------|-------|------|-------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00  | 0.00   | 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 |
| 0.00  | 0.19 | -0.16 | 0.08  | -0.05 | 64.50  | -0.39 | -0.16 | -0.28 | -1.40 | 0.00 | -3.56 | 2.16 |
| 1.00  | 0.31 | 0.08  | -0.37 | 0.76  | 88.00  | -0.16 | 0.32  | 0.28  | 1.43  | 0.00 | -0.73 | 2.16 |
| 2.00  | 0.90 | -0.37 | -0.18 | 0.71  | 86.50  | 0.32  | 0.46  | 0.57  | 2.86  | 0.00 | 0.70  | 2.16 |
| 3.00  | 0.58 | -0.18 | -0.21 | 0.61  | 83.50  | 0.46  | 0.46  | 0.61  | 3.06  | 0.00 | 0.91  | 2.16 |
| 4.00  | 1.23 | -0.21 | -0.70 | 1.72  | 116.00 | 0.46  | 1.01  | 1.17  | 5.94  | 0.00 | 3.78  | 2.16 |
| 5.00  | 2.20 | -0.70 | -0.76 | 2.25  | 131.50 | 1.01  | 1.46  | 1.80  | 9.10  | 0.00 | 6.94  | 2.16 |
| 6.00  | 2.26 | -0.76 | -0.72 | 2.22  | 130.50 | 1.46  | 1.61  | 2.07  | 10.50 | 0.00 | 8.34  | 2.16 |
| 7.00  | 2.09 | -0.72 | -0.64 | 2.01  | 124.50 | 1.61  | 1.56  | 2.06  | 10.44 | 0.00 | 8.28  | 2.16 |
| 8.00  | 2.11 | -0.64 | -0.78 | 2.25  | 131.50 | 1.56  | 1.66  | 2.15  | 10.89 | 0.00 | 8.73  | 2.16 |
| 9.00  | 1.85 | -0.78 | -0.36 | 1.43  | 107.50 | 1.66  | 1.29  | 1.80  | 9.10  | 0.00 | 6.94  | 2.16 |
| 10.00 | 1.12 | -0.36 | -0.39 | 1.16  | 99.50  | 1.29  | 1.02  | 1.42  | 7.19  | 0.00 | 5.03  | 2.16 |
| 11.00 | 1.16 | -0.39 | -0.37 | 1.14  | 99.00  | 1.02  | 0.92  | 1.24  | 6.28  | 0.00 | 4.12  | 2.16 |
| 12.00 | 1.36 | -0.37 | -0.56 | 1.55  | 111.00 | 0.92  | 1.09  | 1.38  | 7.00  | 0.00 | 4.85  | 2.16 |
| 13.00 | 1.60 | -0.56 | -0.48 | 1.52  | 110.00 | 1.09  | 1.13  | 1.47  | 7.46  | 0.00 | 5.30  | 2.16 |
| 14.00 | 1.48 | -0.48 | -0.51 | 1.52  | 110.00 | 1.13  | 1.14  | 1.50  | 7.59  | 0.00 | 5.43  | 2.16 |
| 15.00 | 1.53 | -0.51 | -0.50 | 1.52  | 110.00 | 1.14  | 1.15  | 1.51  | 7.64  | 0.00 | 5.48  | 2.16 |
| 16.00 | 1.49 | -0.50 | -0.49 | 1.48  | 109.00 | 1.15  | 1.13  | 1.50  | 7.57  | 0.00 | 5.41  | 2.16 |
| 17.00 | 1.19 | -0.49 | -0.25 | 0.95  | 93.50  | 1.13  | 0.87  | 1.22  | 6.15  | 0.00 | 3.99  | 2.16 |
| 18.00 | 0.81 | -0.25 | -0.30 | 0.86  | 91.00  | 0.87  | 0.73  | 1.00  | 5.06  | 0.00 | 2.90  | 2.16 |
| 19.00 | 0.91 | -0.30 | -0.30 | 0.91  | 92.50  | 0.73  | 0.71  | 0.94  | 4.75  | 0.00 | 2.59  | 2.16 |
| 20.00 | 0.90 | -0.30 | -0.29 | 0.88  | 91.50  | 0.71  | 0.68  | 0.91  | 4.58  | 0.00 | 2.42  | 2.16 |
| 21.00 | 0.85 | -0.29 | -0.27 | 0.83  | 90.00  | 0.68  | 0.65  | 0.86  | 4.37  | 0.00 | 2.21  | 2.16 |
| 22.00 | 0.84 | -0.27 | -0.29 | 0.86  | 91.00  | 0.65  | 0.65  | 0.86  | 4.35  | 0.00 | 2.19  | 2.16 |
| 23.00 | 1.25 | -0.29 | -0.59 | 1.55  | 111.00 | 0.65  | 0.99  | 1.21  | 6.13  | 0.00 | 3.97  | 2.16 |
| 24.00 | 1.89 | -0.59 | -0.67 | 1.96  | 123.00 | 0.99  | 1.31  | 1.64  | 8.30  | 0.00 | 6.14  | 2.16 |
| 25.00 | 2.01 | -0.67 | -0.66 | 2.00  | 124.00 | 1.31  | 1.44  | 1.86  | 9.44  | 0.00 | 7.28  | 2.16 |
| 26.00 | 1.98 | -0.66 | -0.65 | 1.98  | 123.50 | 1.44  | 1.48  | 1.94  | 9.82  | 0.00 | 7.66  | 2.16 |
| 27.00 | 2.00 | -0.65 | -0.67 | 2.01  | 124.50 | 1.48  | 1.51  | 1.98  | 10.03 | 0.00 | 7.87  | 2.16 |
| 28.00 | 1.75 | -0.67 | -0.44 | 1.52  | 110.00 | 1.51  | 1.28  | 1.75  | 8.85  | 0.00 | 6.69  | 2.16 |
| 29.00 | 1.20 | -0.44 | -0.34 | 1.10  | 98.00  | 1.28  | 1.00  | 1.39  | 7.03  | 0.00 | 4.87  | 2.16 |
| 30.00 | 1.08 | -0.34 | -0.38 | 1.12  | 98.50  | 1.00  | 0.90  | 1.21  | 6.14  | 0.00 | 3.98  | 2.16 |
| 31.00 | 1.16 | -0.38 | -0.38 | 1.16  | 99.50  | 0.90  | 0.89  | 1.17  | 5.93  | 0.00 | 3.77  | 2.16 |
| 32.00 | 1.60 | -0.38 | -0.75 | 1.96  | 123.00 | 0.89  | 1.28  | 1.57  | 7.95  | 0.00 | 5.79  | 2.16 |
| 33.00 | 2.08 | -0.75 | -0.60 | 1.93  | 122.00 | 1.28  | 1.40  | 1.81  | 9.14  | 0.00 | 6.98  | 2.16 |
| 34.00 | 1.91 | -0.60 | -0.68 | 2.00  | 124.00 | 1.40  | 1.47  | 1.92  | 9.71  | 0.00 | 7.55  | 2.16 |
| 35.00 | 2.03 | -0.68 | -0.65 | 2.00  | 124.00 | 1.47  | 1.50  | 1.97  | 9.96  | 0.00 | 7.80  | 2.16 |
| 36.00 | 1.76 | -0.65 | -0.48 | 1.58  | 112.00 | 1.50  | 1.31  | 1.78  | 8.99  | 0.00 | 6.83  | 2.16 |
| 37.00 | 1.28 | -0.48 | -0.34 | 1.14  | 99.00  | 1.31  | 1.02  | 1.42  | 7.21  | 0.00 | 5.05  | 2.16 |
| 38.00 | 1.03 | -0.34 | -0.34 | 1.04  | 96.00  | 1.02  | 0.87  | 1.19  | 6.01  | 0.00 | 3.85  | 2.16 |



Subject 5, Task 4, Trial 1, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 75                  | 0.8900               | 0.3080               | 4.1766          | 1.2864          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 81                  | 0.9100               | 0.3140               | 4.1846          | 1.3140          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 79                  | 0.8800               | 0.3680               | 4.2565          | 1.5664          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 79                  | 0.8700               | 0.3280               | 4.2032          | 1.3787          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 77                  | 0.9100               | 0.3290               | 4.2046          | 1.3833          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 80                  | 0.9100               | 0.2780               | 4.1366          | 1.1500          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 93                  | 0.9100               | 0.5550               | 4.5058          | 2.5007          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 113                 | 0.8000               | 1.0660               | 5.1870          | 5.5293          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 106                 | 0.7800               | 1.0050               | 5.1057          | 5.1312          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 104                 | 0.7900               | 0.9980               | 5.0963          | 5.0861          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 105                 | 0.8100               | 0.9500               | 5.0324          | 4.7807          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 104                 | 0.8200               | 0.9100               | 4.9790          | 4.5309          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 108                 | 0.8200               | 0.8990               | 4.9644          | 4.4630          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 111                 | 0.8400               | 1.0260               | 5.1337          | 5.2671          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 107                 | 0.8400               | 0.8970               | 4.9617          | 4.4506          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 107                 | 0.8400               | 0.9960               | 5.0937          | 5.0733          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 98                  | 0.8400               | 0.9780               | 5.0697          | 4.9581          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 78                  | 0.8900               | 0.5400               | 4.4858          | 2.4223          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 83                  | 0.9300               | 0.3800               | 4.2725          | 1.6236          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 87                  | 0.9400               | 0.2780               | 4.1366          | 1.1500          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 90                  | 0.9100               | 0.2910               | 4.1539          | 1.2088          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 98                  | 0.8900               | 0.3580               | 4.2432          | 1.5191          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 99                  | 0.9000               | 0.6420               | 4.6218          | 2.9672          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 114                 | 0.9000               | 0.8020               | 4.8351          | 3.8777          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 111                 | 0.8600               | 0.9190               | 4.9910          | 4.5868          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 106                 | 0.8300               | 1.1320               | 5.2750          | 5.9713          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 106                 | 0.8300               | 0.9980               | 5.0963          | 5.0861          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 109                 | 0.8200               | 0.9580               | 5.0430          | 4.8312          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 107                 | 0.8200               | 0.9720               | 5.0617          | 4.9199          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 106                 | 0.8200               | 1.0350               | 5.1457          | 5.3258          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 108                 | 0.8300               | 1.0420               | 5.1550          | 5.3715          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 112                 | 0.8400               | 1.0020               | 5.1017          | 5.1119          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 91                  | 0.8500               | 0.7260               | 4.7338          | 3.4367          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 90                  | 0.8700               | 0.5450               | 4.4925          | 2.4484          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 85                  | 0.8700               | 0.4410               | 4.3539          | 1.9200          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 83                  | 0.9100               | 0.2570               | 4.1086          | 1.0559          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 76                  | 0.9100               | 0.2730               | 4.1299          | 1.1275          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 83                  | 0.9000               | 0.2690               | 4.1246          | 1.1095          | 0.0000 |

Subject 5, Task 4, Trial 2, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 85                  | 0.9100               | 0.2890               | 4.9790          | 1.4389          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 88                  | 0.8300               | 0.2580               | 4.8724          | 1.2571          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 88                  | 0.8400               | 0.2770               | 4.8857          | 1.3533          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 84                  | 0.8400               | 0.3100               | 4.8857          | 1.5146          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 86                  | 0.8600               | 0.2610               | 4.9124          | 1.2821          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 85                  | 0.8500               | 0.2750               | 4.8991          | 1.3472          | 0.0000 |
| 3.5                  | 0                     | 0.0000           | 90                  | 0.8800               | 0.5500               | 4.9390          | 2.7165          | 0.0000 |
| 4.0                  | 0                     | 0.0000           | 102                 | 0.8800               | 0.4690               | 4.9390          | 2.3164          | 0.0000 |
| 4.5                  | 0                     | 0.0000           | 108                 | 0.8800               | 0.5450               | 4.9390          | 2.6918          | 0.0000 |
| 5.0                  | 0                     | 0.0000           | 101                 | 0.8400               | 0.6050               | 4.8857          | 2.9559          | 0.0000 |
| 5.5                  | 0                     | 0.0000           | 102                 | 0.8300               | 0.6180               | 4.8724          | 3.0111          | 0.0000 |
| 6.0                  | 0                     | 0.0000           | 98                  | 0.8300               | 0.6240               | 4.8724          | 3.0404          | 0.0000 |
| 6.5                  | 0                     | 0.0000           | 101                 | 0.8200               | 0.6650               | 4.8591          | 3.2313          | 0.0000 |
| 7.0                  | 0                     | 0.0000           | 98                  | 0.8200               | 0.6030               | 4.8591          | 2.9300          | 0.0000 |
| 7.5                  | 0                     | 0.0000           | 108                 | 0.8300               | 0.6000               | 4.8724          | 2.9234          | 0.0000 |
| 8.0                  | 0                     | 0.0000           | 106                 | 0.8300               | 0.6790               | 4.8724          | 3.3084          | 0.0000 |
| 8.5                  | 0                     | 0.0000           | 87                  | 0.8200               | 0.5420               | 4.8591          | 2.6336          | 0.0000 |
| 9.0                  | 0                     | 0.0000           | 82                  | 0.8300               | 0.3740               | 4.8724          | 1.8223          | 0.0000 |
| 9.5                  | 0                     | 0.0000           | 96                  | 0.8700               | 0.2130               | 4.9257          | 1.0492          | 0.0000 |
| 10.0                 | 0                     | 0.0000           | 93                  | 0.8500               | 0.2370               | 4.8991          | 1.1611          | 0.0000 |
| 10.5                 | 0                     | 0.0000           | 86                  | 0.8400               | 0.2680               | 4.8857          | 1.3094          | 0.0000 |
| 11.0                 | 0                     | 0.0000           | 86                  | 0.8400               | 0.2750               | 4.8857          | 1.3436          | 0.0000 |
| 11.5                 | 0                     | 0.0000           | 100                 | 0.8900               | 0.5190               | 4.9524          | 2.5703          | 0.0000 |
| 12.0                 | 0                     | 0.0000           | 126                 | 0.8600               | 0.8740               | 4.9124          | 4.2934          | 0.0000 |
| 12.5                 | 0                     | 0.0000           | 126                 | 0.8100               | 1.1790               | 4.8457          | 5.7131          | 0.0000 |
| 13.0                 | 0                     | 0.0000           | 122                 | 0.8200               | 1.3860               | 4.8591          | 6.7347          | 0.0000 |
| 13.5                 | 0                     | 0.0000           | 115                 | 0.8300               | 1.2500               | 4.8724          | 6.0905          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 119                 | 0.8200               | 1.2020               | 4.8591          | 5.8406          | 0.0000 |
| 14.5                 | 0                     | 0.0000           | 118                 | 0.8200               | 1.2540               | 4.8591          | 6.0933          | 0.0000 |
| 15.0                 | 0                     | 0.0000           | 120                 | 0.8300               | 1.3180               | 4.8724          | 6.4218          | 0.0000 |
| 15.5                 | 0                     | 0.0000           | 120                 | 0.8400               | 1.2720               | 4.8857          | 6.2146          | 0.0000 |
| 16.0                 | 0                     | 0.0000           | 121                 | 0.8500               | 1.3160               | 4.8991          | 6.4471          | 0.0000 |
| 16.5                 | 0                     | 0.0000           | 99                  | 0.8400               | 1.0870               | 4.8857          | 5.3108          | 0.0000 |
| 17.0                 | 0                     | 0.0000           | 94                  | 0.9000               | 0.7110               | 4.9657          | 3.5306          | 0.0000 |
| 17.5                 | 0                     | 0.0000           | 92                  | 0.9100               | 0.5360               | 4.9790          | 2.6688          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 88                  | 0.8900               | 0.4520               | 4.9524          | 2.2385          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 88                  | 0.9500               | 0.2850               | 5.0324          | 1.4342          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 92                  | 0.9300               | 0.2450               | 5.0057          | 1.2264          | 0.0000 |

Subject 5, Test 4

| Equation Type | Equation                                            | Equation Parameters                      |
|---------------|-----------------------------------------------------|------------------------------------------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | $D = 0.33 \quad \alpha = 0.60$           |
| i/t           |                                                     |                                          |
| balance       | $X1 + X2 = X3 + X4$                                 |                                          |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | $\text{Coef} = 0.0287 \quad C = -2.4770$ |
| exogenous     |                                                     |                                          |
| i/t           |                                                     |                                          |
| balance       | $X4 + X6 = X7 + X8$                                 |                                          |
| regression    | $X8 = 1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$  | $D = 0.76 \quad \alpha = 0.21$           |
| gain          | $X9 = Y \cdot X8$                                   | $Y = 4.7916$                             |
| balance       | $X9 = X10 + X11 + X12$                              |                                          |
| regression    | $X10 = \text{Eff} \cdot X11$                        | $\text{Eff} = 0.0000$                    |
| exogenous     | $X12 = \text{RM}$                                   | $\text{RM} = 1.4217$                     |

|   |        |        |    |       |        |        |        |   |    |    |   |   |   |     |   |         |     |
|---|--------|--------|----|-------|--------|--------|--------|---|----|----|---|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X2  | = | -0.1568 | i/t |
| 1 | 1      | -1     | -1 | 0     | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X4  | = | 2.477   |     |
| 0 | 0      | 0      | 0  | 1     | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X5  | = | 78      | ex  |
| 0 | 0      | 0      | 0  | 0     | 1      | 0      | 0      | 0 | 0  | 0  | 0 | 0 | 0 | X6  | = | -0.3929 | i/t |
| 0 | 0      | 0      | 1  | 0     | 1      | -1     | -1     | 0 | 0  | 0  | 0 | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0.2763 | 1.0395 | -1     | 0 | 0  | 0  | 0 | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | -4.792 | 1 | 0  | 0  | 0 | 0 | 0 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | 0 | -1 | 1  | 1 | 1 | 1 | X10 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | 0 | 0  | -1 | 0 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0      | 0      | 0      | 0 | 0  | 0  | 0 | 1 | 1 | X12 | = | 1.42171 |     |



Subject 5, Task 4, model solution

| Time  | X1    | X2    | X3    | X4    | X5     | X6    | X7    | X8    | X9    | X10  | X11   | X12  |
|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|------|-------|------|
| 0.00  | 0.00  | 0.00  | 0.00  | 0.00  | 0.00   | 0.00  | 0.00  | 0.00  | 0.00  | 0.00 | 0.00  | 0.00 |
| 0.00  | 0.08  | -0.16 | 0.17  | -0.24 | 78.00  | -0.39 | -0.26 | -0.38 | -1.80 | 0.00 | -3.22 | 1.42 |
| 1.00  | -0.36 | 0.17  | 0.05  | -0.24 | 78.00  | -0.26 | -0.21 | -0.29 | -1.37 | 0.00 | -2.80 | 1.42 |
| 2.00  | -0.18 | 0.05  | 0.08  | -0.21 | 79.00  | -0.21 | -0.18 | -0.24 | -1.15 | 0.00 | -2.58 | 1.42 |
| 3.00  | -0.23 | 0.08  | 0.07  | -0.22 | 78.50  | -0.18 | -0.17 | -0.23 | -1.09 | 0.00 | -2.51 | 1.42 |
| 4.00  | 0.16  | 0.07  | -0.24 | 0.48  | 103.00 | -0.17 | 0.17  | 0.13  | 0.64  | 0.00 | -0.78 | 1.42 |
| 5.00  | 0.63  | -0.24 | -0.15 | 0.54  | 105.00 | 0.17  | 0.32  | 0.39  | 1.85  | 0.00 | 0.43  | 1.42 |
| 6.00  | 0.50  | -0.15 | -0.18 | 0.52  | 104.50 | 0.32  | 0.37  | 0.48  | 2.28  | 0.00 | 0.86  | 1.42 |
| 7.00  | 0.61  | -0.18 | -0.23 | 0.67  | 109.50 | 0.37  | 0.46  | 0.58  | 2.77  | 0.00 | 1.35  | 1.42 |
| 8.00  | 0.65  | -0.23 | -0.18 | 0.59  | 107.00 | 0.46  | 0.45  | 0.60  | 2.87  | 0.00 | 1.44  | 1.42 |
| 9.00  | 0.28  | -0.18 | 0.05  | 0.05  | 88.00  | 0.45  | 0.18  | 0.32  | 1.52  | 0.00 | 0.10  | 1.42 |
| 10.00 | -0.08 | 0.05  | 0.00  | -0.04 | 85.00  | 0.18  | 0.05  | 0.10  | 0.48  | 0.00 | -0.94 | 1.42 |
| 11.00 | 0.12  | 0.00  | -0.10 | 0.22  | 94.00  | 0.05  | 0.13  | 0.14  | 0.69  | 0.00 | -0.74 | 1.42 |
| 12.00 | 0.45  | -0.10 | -0.23 | 0.58  | 106.50 | 0.13  | 0.33  | 0.38  | 1.80  | 0.00 | 0.38  | 1.42 |
| 13.00 | 0.66  | -0.23 | -0.20 | 0.64  | 108.50 | 0.33  | 0.43  | 0.54  | 2.57  | 0.00 | 1.15  | 1.42 |
| 14.00 | 0.61  | -0.20 | -0.20 | 0.61  | 107.50 | 0.43  | 0.45  | 0.59  | 2.81  | 0.00 | 1.39  | 1.42 |
| 15.00 | 0.59  | -0.20 | -0.19 | 0.58  | 106.50 | 0.45  | 0.44  | 0.59  | 2.81  | 0.00 | 1.39  | 1.42 |
| 16.00 | 0.63  | -0.19 | -0.24 | 0.68  | 110.00 | 0.44  | 0.49  | 0.63  | 3.03  | 0.00 | 1.61  | 1.42 |
| 17.00 | 0.39  | -0.24 | 0.03  | 0.12  | 90.50  | 0.49  | 0.23  | 0.38  | 1.81  | 0.00 | 0.39  | 1.42 |
| 18.00 | -0.08 | 0.03  | 0.02  | -0.07 | 84.00  | 0.23  | 0.05  | 0.12  | 0.56  | 0.00 | -0.86 | 1.42 |
| 19.00 | -0.13 | 0.02  | 0.08  | -0.20 | 79.50  | 0.05  | -0.08 | -0.07 | -0.32 | 0.00 | -1.74 | 1.42 |
| 20.00 | -0.11 | 0.08  | -0.03 | 0.01  | 86.50  | -0.08 | -0.02 | -0.05 | -0.23 | 0.00 | -1.65 | 1.42 |
| 21.00 | 0.04  | -0.03 | 0.02  | -0.01 | 86.00  | -0.02 | -0.01 | -0.02 | -0.10 | 0.00 | -1.52 | 1.42 |
| 22.00 | -0.03 | 0.02  | 0.00  | -0.02 | 85.50  | -0.01 | -0.02 | -0.02 | -0.10 | 0.00 | -1.52 | 1.42 |
| 23.00 | 0.15  | 0.00  | -0.13 | 0.28  | 96.00  | -0.02 | 0.13  | 0.13  | 0.63  | 0.00 | -0.79 | 1.42 |
| 24.00 | 0.46  | -0.13 | -0.19 | 0.52  | 104.50 | 0.13  | 0.30  | 0.35  | 1.68  | 0.00 | 0.26  | 1.42 |
| 25.00 | 0.47  | -0.19 | -0.11 | 0.39  | 100.00 | 0.30  | 0.30  | 0.40  | 1.89  | 0.00 | 0.47  | 1.42 |
| 26.00 | 0.36  | -0.11 | -0.13 | 0.38  | 99.50  | 0.30  | 0.29  | 0.39  | 1.85  | 0.00 | 0.43  | 1.42 |
| 27.00 | 0.51  | -0.13 | -0.22 | 0.59  | 107.00 | 0.29  | 0.39  | 0.49  | 2.35  | 0.00 | 0.93  | 1.42 |
| 28.00 | 0.27  | -0.22 | 0.10  | -0.05 | 84.50  | 0.39  | 0.11  | 0.23  | 1.09  | 0.00 | -0.33 | 1.42 |
| 29.00 | -0.01 | 0.10  | -0.15 | 0.24  | 94.50  | 0.11  | 0.16  | 0.19  | 0.93  | 0.00 | -0.49 | 1.42 |
| 30.00 | 0.19  | -0.15 | 0.06  | -0.01 | 86.00  | 0.16  | 0.05  | 0.10  | 0.46  | 0.00 | -0.96 | 1.42 |
| 31.00 | 0.34  | 0.06  | -0.37 | 0.77  | 113.00 | 0.05  | 0.39  | 0.42  | 2.03  | 0.00 | 0.61  | 1.42 |
| 32.00 | 1.10  | -0.37 | -0.35 | 1.08  | 124.00 | 0.39  | 0.67  | 0.81  | 3.86  | 0.00 | 2.44  | 1.42 |
| 33.00 | 0.97  | -0.35 | -0.27 | 0.88  | 117.00 | 0.67  | 0.67  | 0.88  | 4.22  | 0.00 | 2.80  | 1.42 |
| 34.00 | 0.88  | -0.27 | -0.33 | 0.94  | 119.00 | 0.67  | 0.70  | 0.91  | 4.36  | 0.00 | 2.94  | 1.42 |
| 35.00 | 0.98  | -0.33 | -0.32 | 0.98  | 120.50 | 0.70  | 0.73  | 0.95  | 4.55  | 0.00 | 3.13  | 1.42 |
| 36.00 | 0.60  | -0.32 | -0.01 | 0.29  | 96.50  | 0.73  | 0.40  | 0.62  | 2.97  | 0.00 | 1.55  | 1.42 |
| 37.00 | 0.08  | -0.01 | -0.04 | 0.11  | 90.00  | 0.40  | 0.19  | 0.31  | 1.50  | 0.00 | 0.08  | 1.42 |
| 38.00 | 0.12  | -0.04 | -0.03 | 0.11  | 90.00  | 0.19  | 0.12  | 0.18  | 0.86  | 0.00 | -0.56 | 1.42 |

## APPENDIX F

### Task 5 Data

Subject 1, Task 5, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 79                  | 0.8300                                        | 0.5630                           | 4.8724          | 2.7432                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 80                  | 0.8600                                        | 0.3590                           | 4.9124          | 1.7635                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 82                  | 0.8500                                        | 0.4610                           | 4.8991          | 2.2585                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 81                  | 0.8700                                        | 0.3990                           | 4.9257          | 1.9654                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 83                  | 0.8800                                        | 0.4690                           | 4.9390          | 2.3164                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 83                  | 0.8600                                        | 0.4010                           | 4.9124          | 1.9699                      | 0.0000 |
| 3.5                  | 7                     | 0.0931           | 110                 | 0.8200                                        | 0.6340                           | 4.8591          | 3.0806                      | 0.1522 |
| 4.0                  | 7                     | 0.0931           | 106                 | 0.9000                                        | 0.7930                           | 4.9657          | 3.9378                      | 0.0634 |
| 4.5                  | 7                     | 0.0931           | 109                 | 0.8700                                        | 0.9830                           | 4.9257          | 4.8420                      | 0.0392 |
| 5.0                  | 7                     | 0.0931           | 109                 | 0.8300                                        | 1.0390                           | 4.8724          | 5.0624                      | 0.0359 |
| 5.5                  | 7                     | 0.0931           | 102                 | 0.7900                                        | 1.0750                           | 4.8191          | 5.1805                      | 0.0343 |
| 6.0                  | 7                     | 0.0931           | 105                 | 0.8300                                        | 1.0590                           | 4.8724          | 5.1599                      | 0.0346 |
| 6.5                  | 3                     | 0.0497           | 103                 | 0.8100                                        | 1.1590                           | 4.8457          | 5.6162                      | 0.0156 |
| 7.0                  | 3                     | 0.0497           | 94                  | 0.8400                                        | 0.8830                           | 4.8857          | 4.3141                      | 0.0263 |
| 7.5                  | 3                     | 0.0497           | 91                  | 0.8500                                        | 1.0090                           | 4.8991          | 4.9431                      | 0.0197 |
| 8.0                  | 3                     | 0.0497           | 98                  | 0.8500                                        | 0.9430                           | 4.8991          | 4.6198                      | 0.0227 |
| 8.5                  | 2                     | 0.0311           | 96                  | 0.8700                                        | 0.9790                           | 4.9257          | 4.8223                      | 0.0129 |
| 9.0                  | 2                     | 0.0311           | 94                  | 0.8700                                        | 0.9470                           | 4.9257          | 4.6646                      | 0.0138 |
| 9.5                  | 2                     | 0.0311           | 100                 | 0.8800                                        | 0.8820                           | 4.9390          | 4.3562                      | 0.0160 |
| 10.0                 | 2                     | 0.0311           | 97                  | 0.8700                                        | 0.9310                           | 4.9257          | 4.5858                      | 0.0143 |
| 10.5                 | 2                     | 0.0311           | 98                  | 0.8700                                        | 0.9450                           | 4.9257          | 4.6548                      | 0.0138 |
| 11.0                 | 2                     | 0.0311           | 100                 | 0.8500                                        | 0.9950                           | 4.8991          | 4.8746                      | 0.0126 |
| 11.5                 | 2                     | 0.0311           | 99                  | 0.8400                                        | 0.9280                           | 4.8857          | 4.5339                      | 0.0146 |
| 12.0                 | 2                     | 0.0311           | 99                  | 0.8500                                        | 0.9530                           | 4.8991          | 4.6688                      | 0.0137 |
| 12.5                 | 2                     | 0.0311           | 98                  | 0.8600                                        | 0.9180                           | 4.9124          | 4.5096                      | 0.0148 |
| 13.0                 | 2                     | 0.0311           | 100                 | 0.8500                                        | 0.7530                           | 4.8991          | 3.6890                      | 0.0243 |
| 13.5                 | 0                     | 0.0000           | 88                  | 0.8600                                        | 1.0010                           | 4.9124          | 4.9173                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 82                  | 0.8500                                        | 0.6810                           | 4.8991          | 3.3363                      | 0.0000 |
| 14.5                 | 10                    | 0.1490           | 107                 | 0.8900                                        | 0.8370                           | 4.9524          | 4.1451                      | 0.0920 |
| 15.0                 | 10                    | 0.1490           | 107                 | 0.9200                                        | 0.8760                           | 4.9924          | 4.3733                      | 0.0806 |
| 15.5                 | 10                    | 0.1490           | 101                 | 0.8700                                        | 1.1310                           | 4.9257          | 5.5710                      | 0.0489 |
| 16.0                 | 10                    | 0.1490           | 102                 | 0.8500                                        | 1.1450                           | 4.8991          | 5.6094                      | 0.0483 |
| 16.5                 | 10                    | 0.1490           | 101                 | 0.8300                                        | 1.0800                           | 4.8724          | 5.2622                      | 0.0544 |
| 17.0                 | 10                    | 0.1490           | 105                 | 0.8400                                        | 1.1280                           | 4.8857          | 5.5111                      | 0.0499 |
| 17.5                 | 0                     | 0.0000           | 92                  | 0.8400                                        | 1.5520                           | 4.8857          | 7.5826                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 75                  | 0.8800                                        | 0.7950                           | 4.9390          | 3.9265                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 72                  | 0.8600                                        | 0.5920                           | 4.9124          | 2.9081                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 74                  | 0.8700                                        | 0.5400                           | 4.9257          | 2.6599                      | 0.0000 |
| 19.5                 | 0                     | 0.0000           | 74                  | 0.8800                                        | 0.5220                           | 4.9390          | 2.5782                      | 0.0000 |
| 20.0                 | 0                     | 0.0000           | 73                  | 0.9000                                        | 0.4730                           | 4.9657          | 2.3488                      | 0.0000 |



Subject 1, Test 5

| Equation Type | Equation                                | Equation Parameters |        |       |         |
|---------------|-----------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha X2 + (1-\alpha) X3)$ | D=                  | 0.33   | alfa= | 0.60    |
| i/t           |                                         |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                     |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha X6 + (1-\alpha) X7)$ | D=                  | 0.76   | alfa= | 0.21    |
| gain          | $X4 = \text{Coef} * X5 + C$             | Coef =              | 0.0349 | C =   | -2.3197 |
| i/t           |                                         |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                     |                     |        |       |         |
| gain          | $X9 = Y * X8$                           | Y =                 | 4.9087 |       |         |
| balance       | $X9 = X10 + X11 + X12$                  |                     |        |       |         |
| exogenous     |                                         |                     |        |       |         |
| regression    | $X10 = \text{Eff} * X11$                | Eff =               | 0.0311 |       |         |
| exogenous     | $X12 = \text{RM}$                       | RM =                | 2.3756 |       |         |

|   |        |        |    |       |         |         |       |    |   |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|---|----|-------|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.27632 | 1.03947 | 0     | 0  | 0 | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.035 | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X5  | = | 2.31969 |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | -1    | 0  | 0 | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.909 | -1 | 0 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | -1 | 0.031 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 1 | X12 | = | 2.37563 |     |

Subject 1, Task 5, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.57 | -0.19 | -0.18 | 0.56 | 82.41  | -0.48 | -0.41 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 1.00  | 0.53 | -0.18 | -0.16 | 0.51 | 81.07  | -0.41 | -0.38 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 2.00  | 0.49 | -0.16 | -0.16 | 0.49 | 80.60  | -0.38 | -0.37 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 3.00  | 0.49 | -0.16 | -0.16 | 0.49 | 80.43  | -0.37 | -0.37 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 4.00  | 0.66 | -0.16 | -0.31 | 0.81 | 89.56  | -0.37 | -0.68 | 1.11 | 5.46 | 0.09 | 3.00 | 2.38 |
| 5.00  | 0.97 | -0.31 | -0.34 | 1.00 | 95.24  | -0.68 | -0.79 | 1.11 | 5.46 | 0.09 | 3.00 | 2.38 |
| 6.00  | 1.06 | -0.34 | -0.36 | 1.07 | 97.26  | -0.79 | -0.82 | 1.11 | 5.46 | 0.09 | 3.00 | 2.38 |
| 7.00  | 1.01 | -0.36 | -0.30 | 0.95 | 93.69  | -0.82 | -0.69 | 0.82 | 4.02 | 0.05 | 1.60 | 2.38 |
| 8.00  | 0.88 | -0.30 | -0.28 | 0.87 | 91.28  | -0.69 | -0.65 | 0.82 | 4.02 | 0.05 | 1.60 | 2.38 |
| 9.00  | 0.81 | -0.28 | -0.24 | 0.77 | 88.59  | -0.65 | -0.57 | 0.69 | 3.41 | 0.03 | 1.00 | 2.38 |
| 10.00 | 0.73 | -0.24 | -0.24 | 0.72 | 87.15  | -0.57 | -0.54 | 0.69 | 3.41 | 0.03 | 1.00 | 2.38 |
| 11.00 | 0.71 | -0.24 | -0.23 | 0.70 | 86.64  | -0.54 | -0.53 | 0.69 | 3.41 | 0.03 | 1.00 | 2.38 |
| 12.00 | 0.70 | -0.23 | -0.23 | 0.70 | 86.45  | -0.53 | -0.53 | 0.69 | 3.41 | 0.03 | 1.00 | 2.38 |
| 13.00 | 0.70 | -0.23 | -0.23 | 0.70 | 86.39  | -0.53 | -0.53 | 0.69 | 3.41 | 0.03 | 1.00 | 2.38 |
| 14.00 | 0.64 | -0.23 | -0.18 | 0.59 | 83.30  | -0.53 | -0.42 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 15.00 | 0.81 | -0.18 | -0.40 | 1.03 | 96.09  | -0.42 | -0.88 | 1.49 | 7.32 | 0.15 | 4.79 | 2.38 |
| 16.00 | 1.28 | -0.40 | -0.45 | 1.33 | 104.54 | -0.88 | -1.04 | 1.49 | 7.32 | 0.15 | 4.79 | 2.38 |
| 17.00 | 1.41 | -0.45 | -0.48 | 1.43 | 107.54 | -1.04 | -1.10 | 1.49 | 7.32 | 0.15 | 4.79 | 2.38 |
| 18.00 | 1.18 | -0.48 | -0.25 | 0.96 | 93.90  | -1.10 | -0.63 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 19.00 | 0.71 | -0.25 | -0.20 | 0.65 | 85.15  | -0.63 | -0.46 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |
| 20.00 | 0.57 | -0.20 | -0.17 | 0.54 | 82.04  | -0.46 | -0.40 | 0.48 | 2.38 | 0.00 | 0.00 | 2.38 |

Subject 2, Task 5, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 77                  | 0.8700                                        | 0.4200                           | 4.9257          | 2.0688                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 75                  | 0.8600                                        | 0.3600                           | 4.9124          | 1.7685                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 80                  | 0.8600                                        | 0.3910                           | 4.9124          | 1.9207                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 80                  | 0.8700                                        | 0.3690                           | 4.9257          | 1.8176                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 80                  | 0.8500                                        | 0.3590                           | 4.8991          | 1.7588                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 80                  | 0.8600                                        | 0.3400                           | 4.9124          | 1.6702                      | 0.0000 |
| 3.5                  | 7                     | 0.0931           | 98                  | 0.8300                                        | 0.4280                           | 4.8724          | 2.0854                      | 1.5878 |
| 4.0                  | 7                     | 0.0931           | 98                  | 0.8300                                        | 0.5950                           | 4.8724          | 2.8991                      | 0.1068 |
| 4.5                  | 7                     | 0.0931           | 101                 | 0.8400                                        | 0.5690                           | 4.8857          | 2.7800                      | 0.1237 |
| 5.0                  | 7                     | 0.0931           | 98                  | 0.8100                                        | 0.7580                           | 4.8457          | 3.6731                      | 0.0566 |
| 5.5                  | 7                     | 0.0931           | 98                  | 0.7700                                        | 0.6860                           | 4.7924          | 3.2876                      | 0.0739 |
| 6.0                  | 7                     | 0.0931           | 98                  | 0.7700                                        | 0.6810                           | 4.7924          | 3.2636                      | 0.0753 |
| 6.5                  | 3                     | 0.0497           | 97                  | 0.7500                                        | 0.8520                           | 4.7658          | 4.0604                      | 0.0239 |
| 7.0                  | 3                     | 0.0497           | 88                  | 0.8000                                        | 0.6860                           | 4.8324          | 3.3150                      | 0.0373 |
| 7.5                  | 3                     | 0.0497           | 85                  | 0.8000                                        | 0.6430                           | 4.8324          | 3.1072                      | 0.0442 |
| 8.0                  | 3                     | 0.0497           | 89                  | 0.7600                                        | 0.6400                           | 4.7791          | 3.0586                      | 0.0462 |
| 8.5                  | 2                     | 0.0311           | 92                  | 0.7900                                        | 0.6550                           | 4.8191          | 3.1565                      | 0.0261 |
| 9.0                  | 2                     | 0.0311           | 98                  | 0.7800                                        | 0.6600                           | 4.8057          | 3.1718                      | 0.0258 |
| 9.5                  | 2                     | 0.0311           | 102                 | 0.8300                                        | 0.7740                           | 4.8724          | 3.7712                      | 0.0172 |
| 10.0                 | 2                     | 0.0311           | 98                  | 0.8200                                        | 0.6380                           | 4.8591          | 3.1001                      | 0.0274 |
| 10.5                 | 2                     | 0.0311           | 97                  | 0.8200                                        | 0.5790                           | 4.8591          | 2.8134                      | 0.0366 |
| 11.0                 | 2                     | 0.0311           | 98                  | 0.8000                                        | 0.5980                           | 4.8324          | 2.8898                      | 0.0336 |
| 11.5                 | 2                     | 0.0311           | 99                  | 0.8200                                        | 0.6460                           | 4.8591          | 3.1390                      | 0.0265 |
| 12.0                 | 2                     | 0.0311           | 98                  | 0.7800                                        | 0.6810                           | 4.8057          | 3.2727                      | 0.0238 |
| 12.5                 | 2                     | 0.0311           | 95                  | 0.8100                                        | 0.6510                           | 4.8457          | 3.1546                      | 0.0261 |
| 13.0                 | 2                     | 0.0311           | 98                  | 0.8200                                        | 0.6120                           | 4.8591          | 2.9737                      | 0.0308 |
| 13.5                 | 0                     | 0.0000           | 81                  | 0.7500                                        | 0.8920                           | 4.7658          | 4.2510                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 72                  | 0.7800                                        | 0.5100                           | 4.8057          | 2.4509                      | 0.0000 |
| 14.5                 | 10                    | 0.1490           | 104                 | 0.7800                                        | 0.6750                           | 4.8057          | 3.2439                      | 0.1283 |
| 15.0                 | 10                    | 0.1490           | 106                 | 0.8200                                        | 0.7880                           | 4.8591          | 3.8289                      | 0.0853 |
| 15.5                 | 10                    | 0.1490           | 104                 | 0.8200                                        | 0.7950                           | 4.8591          | 3.8630                      | 0.0837 |
| 16.0                 | 10                    | 0.1490           | 98                  | 0.8200                                        | 0.8990                           | 4.8591          | 4.3683                      | 0.0652 |
| 16.5                 | 10                    | 0.1490           | 101                 | 0.8000                                        | 0.7990                           | 4.8324          | 3.8611                      | 0.0838 |
| 17.0                 | 10                    | 0.1490           | 100                 | 0.7900                                        | 0.8570                           | 4.8191          | 4.1299                      | 0.0728 |
| 17.5                 | 0                     | 0.0000           | 86                  | 0.7600                                        | 1.0240                           | 4.7791          | 4.8938                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 73                  | 0.8100                                        | 0.7080                           | 4.8457          | 3.4308                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 73                  | 0.8300                                        | 0.4920                           | 4.8724          | 2.3972                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 69                  | 0.8600                                        | 0.4420                           | 4.9124          | 2.1713                      | 0.0000 |
| 19.5                 | 0                     | 0.0000           | 70                  | 0.8600                                        | 0.4120                           | 4.9124          | 2.0239                      | 0.0000 |
| 20.0                 | 0                     | 0.0000           | 71                  | 0.8800                                        | 0.3460                           | 4.9390          | 1.7089                      | 0.0000 |

Subject 2, Test 5

| Equation Type | Equation                                            | Equation Parameters |        |             |
|---------------|-----------------------------------------------------|---------------------|--------|-------------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.33   | alfa= 0.60  |
| i/t           |                                                     |                     |        |             |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |             |
| regression    | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.76   | alfa= 0.21  |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0293 | C = -1.9650 |
| i/t           |                                                     |                     |        |             |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |             |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 4.8511 |             |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |             |
| exogenous     |                                                     |                     |        |             |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0559 |             |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 1.9336 |             |

|   |        |        |    |       |         |         |       |    |   |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|---|----|-------|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.27632 | 1.03947 | 0     | 0  | 0 | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X5  | = | 1.965   |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | -1    | 0  | 0 | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.851 | -1 | 0 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | -1 | 0.056 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 1 | X12 | = | 1.93357 |     |



Subject 2, Task 5, model solution

| Time  | X1   | X2    | X3    | X4   | X5    | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|-------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00  | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.54 | -0.19 | -0.16 | 0.51 | 84.57 | -0.48 | -0.37 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 1.00  | 0.46 | -0.16 | -0.14 | 0.44 | 82.05 | -0.37 | -0.33 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 2.00  | 0.42 | -0.14 | -0.14 | 0.41 | 81.16 | -0.33 | -0.31 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 3.00  | 0.41 | -0.14 | -0.13 | 0.40 | 80.84 | -0.31 | -0.31 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 4.00  | 0.50 | -0.13 | -0.22 | 0.59 | 87.04 | -0.31 | -0.48 | 0.76 | 3.69 | 0.09 | 1.67 | 1.93 |
| 5.00  | 0.68 | -0.22 | -0.24 | 0.70 | 90.92 | -0.48 | -0.54 | 0.76 | 3.69 | 0.09 | 1.67 | 1.93 |
| 6.00  | 0.73 | -0.24 | -0.25 | 0.74 | 92.30 | -0.54 | -0.57 | 0.76 | 3.69 | 0.09 | 1.67 | 1.93 |
| 7.00  | 0.70 | -0.25 | -0.21 | 0.67 | 89.84 | -0.57 | -0.49 | 0.59 | 2.87 | 0.05 | 0.89 | 1.93 |
| 8.00  | 0.63 | -0.21 | -0.20 | 0.62 | 88.19 | -0.49 | -0.46 | 0.59 | 2.87 | 0.05 | 0.89 | 1.93 |
| 9.00  | 0.59 | -0.20 | -0.18 | 0.56 | 86.34 | -0.46 | -0.42 | 0.52 | 2.52 | 0.03 | 0.56 | 1.93 |
| 10.00 | 0.54 | -0.18 | -0.18 | 0.54 | 85.35 | -0.42 | -0.40 | 0.52 | 2.52 | 0.03 | 0.56 | 1.93 |
| 11.00 | 0.53 | -0.18 | -0.17 | 0.53 | 85.00 | -0.40 | -0.40 | 0.52 | 2.52 | 0.03 | 0.56 | 1.93 |
| 12.00 | 0.52 | -0.17 | -0.17 | 0.52 | 84.87 | -0.40 | -0.40 | 0.52 | 2.52 | 0.03 | 0.56 | 1.93 |
| 13.00 | 0.52 | -0.17 | -0.17 | 0.52 | 84.83 | -0.40 | -0.40 | 0.52 | 2.52 | 0.03 | 0.56 | 1.93 |
| 14.00 | 0.49 | -0.17 | -0.14 | 0.46 | 82.70 | -0.40 | -0.34 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 15.00 | 0.59 | -0.14 | -0.27 | 0.72 | 91.49 | -0.34 | -0.60 | 0.98 | 4.75 | 0.15 | 2.67 | 1.93 |
| 16.00 | 0.86 | -0.27 | -0.30 | 0.89 | 97.29 | -0.60 | -0.69 | 0.98 | 4.75 | 0.15 | 2.67 | 1.93 |
| 17.00 | 0.93 | -0.30 | -0.32 | 0.95 | 99.35 | -0.69 | -0.73 | 0.98 | 4.75 | 0.15 | 2.67 | 1.93 |
| 18.00 | 0.80 | -0.32 | -0.19 | 0.67 | 89.98 | -0.73 | -0.45 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 19.00 | 0.53 | -0.19 | -0.15 | 0.50 | 83.97 | -0.45 | -0.36 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |
| 20.00 | 0.45 | -0.15 | -0.14 | 0.43 | 81.84 | -0.36 | -0.32 | 0.40 | 1.93 | 0.00 | 0.00 | 1.93 |

Subject 3, Task 5, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO2/O2<br>**** | VO2<br>l/min<br>**** | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|----------------------|----------------------|-----------------|-----------------|--------|
| 0.5                  | 0                     | 0.0000           | 75                  | 0.7700               | 0.3060               | 4.7924          | 1.4665          | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 69                  | 0.7200               | 0.3680               | 4.7258          | 1.7391          | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 74                  | 0.7400               | 0.2910               | 4.7524          | 1.3830          | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 73                  | 0.7000               | 0.2220               | 4.6991          | 1.0432          | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 64                  | 0.7600               | 0.2550               | 4.7791          | 1.2187          | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 76                  | 0.7300               | 0.2450               | 4.7391          | 1.1611          | 0.0000 |
| 3.5                  | 7                     | 0.0931           | 90                  | 0.8700               | 0.5230               | 4.9257          | 2.5761          | 0.0817 |
| 4.0                  | 7                     | 0.0931           | 95                  | 0.8300               | 0.6030               | 4.8724          | 2.9381          | 0.0620 |
| 4.5                  | 7                     | 0.0931           | 98                  | 0.8300               | 0.6640               | 4.8724          | 3.2353          | 0.0518 |
| 5.0                  | 7                     | 0.0931           | 98                  | 0.7800               | 0.6680               | 4.8057          | 3.2102          | 0.0525 |
| 5.5                  | 7                     | 0.0931           | 95                  | 0.7500               | 0.7830               | 4.7658          | 3.7316          | 0.0406 |
| 6.0                  | 7                     | 0.0931           | 100                 | 0.7300               | 0.7580               | 4.7391          | 3.5922          | 0.0432 |
| 6.5                  | 3                     | 0.0497           | 85                  | 0.7000               | 0.7830               | 4.6991          | 3.6794          | 0.0217 |
| 7.0                  | 3                     | 0.0497           | 91                  | 0.7100               | 0.5630               | 4.7124          | 2.6531          | 0.0394 |
| 7.5                  | 3                     | 0.0497           | 80                  | 0.7200               | 0.6630               | 4.7258          | 3.1332          | 0.0286 |
| 8.0                  | 3                     | 0.0497           | 84                  | 0.7000               | 0.5530               | 4.6991          | 2.5986          | 0.0412 |
| 8.5                  | 2                     | 0.0311           | 92                  | 0.6900               | 0.3190               | 4.6858          | 1.4948          | 0.2561 |
| 9.0                  | 2                     | 0.0311           | 88                  | 0.7700               | 1.0380               | 4.7924          | 4.9745          | 0.0086 |
| 9.5                  | 2                     | 0.0311           | 93                  | 0.7300               | 0.6060               | 4.7391          | 2.8719          | 0.0208 |
| 10.0                 | 2                     | 0.0311           | 87                  | 0.7300               | 0.6460               | 4.7391          | 3.0615          | 0.0184 |
| 10.5                 | 2                     | 0.0311           | 95                  | 0.7200               | 0.5690               | 4.7258          | 2.6890          | 0.0236 |
| 11.0                 | 2                     | 0.0311           | 85                  | 0.7100               | 0.5370               | 4.7124          | 2.5306          | 0.0269 |
| 11.5                 | 2                     | 0.0311           | 92                  | 0.7200               | 0.4720               | 4.7258          | 2.2306          | 0.0363 |
| 12.0                 | 2                     | 0.0311           | 92                  | 0.7300               | 0.6370               | 4.7391          | 3.0188          | 0.0189 |
| 12.5                 | 2                     | 0.0311           | 90                  | 0.7300               | 0.6220               | 4.7391          | 2.9477          | 0.0198 |
| 13.0                 | 2                     | 0.0311           | 100                 | 0.7300               | 0.7060               | 4.7391          | 3.3458          | 0.0158 |
| 13.5                 | 0                     | 0.0000           | 81                  | 0.7600               | 1.1220               | 4.7791          | 5.3621          | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 82                  | 0.7400               | 0.4200               | 4.7524          | 1.9960          | 0.0000 |
| 14.5                 | 10                    | 0.1490           | 87                  | 0.7600               | 0.7400               | 4.7791          | 3.5365          | 0.0729 |
| 15.0                 | 10                    | 0.1490           | 94                  | 0.7800               | 0.5390               | 4.8057          | 2.5903          | 0.1356 |
| 15.5                 | 10                    | 0.1490           | 97                  | 0.7500               | 0.7460               | 4.7658          | 3.5552          | 0.0722 |
| 16.0                 | 10                    | 0.1490           | 95                  | 0.7300               | 0.8930               | 4.7391          | 4.2320          | 0.0544 |
| 16.5                 | 10                    | 0.1490           | 100                 | 0.7500               | 1.0980               | 4.7658          | 5.2328          | 0.0398 |
| 17.0                 | 10                    | 0.1490           | 89                  | 0.7700               | 0.8130               | 4.7924          | 3.8962          | 0.0620 |
| 17.5                 | 0                     | 0.0000           | 85                  | 0.7900               | 0.5220               | 4.8191          | 2.5156          | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 77                  | 0.7800               | 0.4270               | 4.8057          | 2.0521          | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 74                  | 0.8000               | 0.3450               | 4.8324          | 1.6672          | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 71                  | 0.8400               | 0.3060               | 4.8857          | 1.4950          | 0.0000 |
| 19.5                 | 0                     | 0.0000           | 74                  | 0.8200               | 0.2300               | 4.8591          | 1.1176          | 0.0000 |
| 20.0                 | 0                     | 0.0000           | 76                  | 0.8100               | 0.3410               | 4.8457          | 1.6524          | 0.0000 |



## Subject 3, Test 5

| Equation Type | Equation                                            | Equation Parameters |        |       |         |
|---------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | -0.33  | alfa= | 0.60    |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.76   | alfa= | 0.21    |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0305 | C =   | -1.9627 |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 4.7717 |       |         |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| exogenous     |                                                     |                     |        |       |         |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0377 |       |         |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 1.1589 |       |         |

|   |        |        |    |       |         |         |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.27632 | 1.03947 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.031 | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 1.9627  |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | 0     | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.772 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | -1 | 0.038 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 1 | 1 | X12 | = | 1.15891 |     |

Subject 3, Task 5, model solution

| Time  | X1   | X2    | X3    | X4   | X5    | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|-------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00  | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.50 | -0.19 | -0.13 | 0.43 | 78.56 | -0.48 | -0.29 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 1.00  | 0.34 | -0.13 | -0.09 | 0.31 | 74.53 | -0.29 | -0.22 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 2.00  | 0.27 | -0.09 | -0.09 | 0.27 | 73.10 | -0.22 | -0.20 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 3.00  | 0.26 | -0.09 | -0.08 | 0.25 | 72.59 | -0.20 | -0.19 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 4.00  | 0.40 | -0.08 | -0.20 | 0.52 | 81.40 | -0.19 | -0.45 | 0.78 | 3.72 | 0.09 | 2.47 | 1.16 |
| 5.00  | 0.66 | -0.20 | -0.24 | 0.69 | 86.91 | -0.45 | -0.54 | 0.78 | 3.72 | 0.09 | 2.47 | 1.16 |
| 6.00  | 0.73 | -0.24 | -0.25 | 0.75 | 88.87 | -0.54 | -0.58 | 0.78 | 3.72 | 0.09 | 2.47 | 1.16 |
| 7.00  | 0.70 | -0.25 | -0.20 | 0.64 | 85.37 | -0.58 | -0.46 | 0.53 | 2.53 | 0.05 | 1.32 | 1.16 |
| 8.00  | 0.58 | -0.20 | -0.18 | 0.57 | 83.02 | -0.46 | -0.42 | 0.53 | 2.53 | 0.05 | 1.32 | 1.16 |
| 9.00  | 0.52 | -0.18 | -0.15 | 0.49 | 80.39 | -0.42 | -0.36 | 0.42 | 2.02 | 0.03 | 0.83 | 1.16 |
| 10.00 | 0.45 | -0.15 | -0.15 | 0.45 | 78.98 | -0.36 | -0.33 | 0.42 | 2.02 | 0.03 | 0.83 | 1.16 |
| 11.00 | 0.43 | -0.15 | -0.14 | 0.43 | 78.48 | -0.33 | -0.33 | 0.42 | 2.02 | 0.03 | 0.83 | 1.16 |
| 12.00 | 0.43 | -0.14 | -0.14 | 0.43 | 78.30 | -0.33 | -0.32 | 0.42 | 2.02 | 0.03 | 0.83 | 1.16 |
| 13.00 | 0.42 | -0.14 | -0.14 | 0.42 | 78.23 | -0.32 | -0.32 | 0.42 | 2.02 | 0.03 | 0.83 | 1.16 |
| 14.00 | 0.37 | -0.14 | -0.10 | 0.33 | 75.21 | -0.32 | -0.23 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 15.00 | 0.52 | -0.10 | -0.29 | 0.71 | 87.72 | -0.23 | -0.62 | 1.10 | 5.26 | 0.15 | 3.96 | 1.16 |
| 16.00 | 0.92 | -0.29 | -0.33 | 0.96 | 95.98 | -0.62 | -0.76 | 1.10 | 5.26 | 0.15 | 3.96 | 1.16 |
| 17.00 | 1.03 | -0.33 | -0.35 | 1.05 | 98.91 | -0.76 | -0.81 | 1.10 | 5.26 | 0.15 | 3.96 | 1.16 |
| 18.00 | 0.84 | -0.35 | -0.16 | 0.65 | 85.57 | -0.81 | -0.41 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 19.00 | 0.43 | -0.16 | -0.11 | 0.39 | 77.02 | -0.41 | -0.26 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |
| 20.00 | 0.32 | -0.11 | -0.09 | 0.29 | 73.98 | -0.26 | -0.21 | 0.24 | 1.16 | 0.00 | 0.00 | 1.16 |

Subject 4, Task 5, experimentally collected data

| Time<br>min.<br>**** | Work<br>Watts<br>**** | Work<br>Kcal/min | HR<br>B/min<br>**** | RQ<br>CO <sub>2</sub> /O <sub>2</sub><br>**** | VO <sub>2</sub><br>l/min<br>**** | Yield<br>Kcal/l | VO <sub>2</sub><br>Kcal/min | Eff    |
|----------------------|-----------------------|------------------|---------------------|-----------------------------------------------|----------------------------------|-----------------|-----------------------------|--------|
| 0.5                  | 0                     | 0.0000           | 89                  | 0.8600                                        | 0.5590                           | 4.9124          | 2.7460                      | 0.0000 |
| 1.0                  | 0                     | 0.0000           | 88                  | 0.9100                                        | 0.3790                           | 4.9790          | 1.8871                      | 0.0000 |
| 1.5                  | 0                     | 0.0000           | 82                  | 0.9000                                        | 0.2790                           | 4.9657          | 1.3854                      | 0.0000 |
| 2.0                  | 0                     | 0.0000           | 82                  | 0.8400                                        | 0.3440                           | 4.8857          | 1.6807                      | 0.0000 |
| 2.5                  | 0                     | 0.0000           | 87                  | 0.8200                                        | 0.3970                           | 4.8591          | 1.9290                      | 0.0000 |
| 3.0                  | 0                     | 0.0000           | 80                  | 0.7900                                        | 0.3290                           | 4.8191          | 1.5855                      | 0.0000 |
| 3.5                  | 7                     | 0.0931           | 92                  | 0.8700                                        | 0.5830                           | 4.9257          | 2.8717                      | 0.1373 |
| 4.0                  | 7                     | 0.0931           | 100                 | 0.8800                                        | 0.7150                           | 4.9390          | 3.5314                      | 0.0696 |
| 4.5                  | 7                     | 0.0931           | 107                 | 0.8500                                        | 0.9090                           | 4.8991          | 4.4532                      | 0.0412 |
| 5.0                  | 7                     | 0.0931           | 96                  | 0.8200                                        | 0.8930                           | 4.8591          | 4.3391                      | 0.0434 |
| 5.5                  | 7                     | 0.0931           | 103                 | 0.8000                                        | 0.9130                           | 4.8324          | 4.4120                      | 0.0420 |
| 6.0                  | 7                     | 0.0931           | 101                 | 0.8100                                        | 0.9290                           | 4.8457          | 4.5017                      | 0.0403 |
| 6.5                  | 3                     | 0.0497           | 106                 | 0.8200                                        | 0.9780                           | 4.8591          | 4.7522                      | 0.0191 |
| 7.0                  | 3                     | 0.0497           | 97                  | 0.8300                                        | 0.8810                           | 4.8724          | 4.2926                      | 0.0232 |
| 7.5                  | 3                     | 0.0497           | 99                  | 0.8200                                        | 0.8040                           | 4.8591          | 3.9067                      | 0.0283 |
| 8.0                  | 3                     | 0.0497           | 102                 | 0.8300                                        | 0.8000                           | 4.8724          | 3.8979                      | 0.0284 |
| 8.5                  | 2                     | 0.0311           | 100                 | 0.8400                                        | 0.6640                           | 4.8857          | 3.2441                      | 0.0279 |
| 9.0                  | 2                     | 0.0311           | 105                 | 0.8200                                        | 0.7860                           | 4.8591          | 3.8192                      | 0.0184 |
| 9.5                  | 2                     | 0.0311           | 101                 | 0.8400                                        | 0.7720                           | 4.8857          | 3.7718                      | 0.0190 |
| 10.0                 | 2                     | 0.0311           | 98                  | 0.8300                                        | 0.7710                           | 4.8724          | 3.7566                      | 0.0191 |
| 10.5                 | 2                     | 0.0311           | 103                 | 0.8100                                        | 0.8090                           | 4.8457          | 3.9202                      | 0.0174 |
| 11.0                 | 2                     | 0.0311           | 99                  | 0.8300                                        | 0.8340                           | 4.8724          | 4.0636                      | 0.0161 |
| 11.5                 | 2                     | 0.0311           | 98                  | 0.8500                                        | 0.7600                           | 4.8991          | 3.7233                      | 0.0195 |
| 12.0                 | 2                     | 0.0311           | 99                  | 0.8100                                        | 0.8020                           | 4.8457          | 3.8863                      | 0.0177 |
| 12.5                 | 2                     | 0.0311           | 101                 | 0.8200                                        | 0.8150                           | 4.8591          | 3.9601                      | 0.0170 |
| 13.0                 | 2                     | 0.0311           | 101                 | 0.8400                                        | 0.8110                           | 4.8857          | 3.9623                      | 0.0170 |
| 13.5                 | 0                     | 0.0000           | 102                 | 0.8200                                        | 0.9780                           | 4.8591          | 4.7522                      | 0.0000 |
| 14.0                 | 0                     | 0.0000           | 96                  | 0.8800                                        | 0.6310                           | 4.9390          | 3.1165                      | 0.0000 |
| 14.5                 | 10                    | 0.1490           | 101                 | 0.8500                                        | 0.7700                           | 4.8991          | 3.7723                      | 0.0978 |
| 15.0                 | 10                    | 0.1490           | 111                 | 0.8500                                        | 0.9670                           | 4.8991          | 4.7374                      | 0.0599 |
| 15.5                 | 10                    | 0.1490           | 108                 | 0.8200                                        | 1.0130                           | 4.8591          | 4.9222                      | 0.0558 |
| 16.0                 | 10                    | 0.1490           | 105                 | 0.8100                                        | 1.0780                           | 4.8457          | 5.2237                      | 0.0501 |
| 16.5                 | 10                    | 0.1490           | 108                 | 0.8400                                        | 1.0400                           | 4.8857          | 5.0811                      | 0.0526 |
| 17.0                 | 10                    | 0.1490           | 108                 | 0.8700                                        | 0.9550                           | 4.9257          | 4.7041                      | 0.0607 |
| 17.5                 | 0                     | 0.0000           | 100                 | 0.7900                                        | 0.9950                           | 4.8191          | 4.7950                      | 0.0000 |
| 18.0                 | 0                     | 0.0000           | 91                  | 0.8100                                        | 0.7250                           | 4.8457          | 3.5132                      | 0.0000 |
| 18.5                 | 0                     | 0.0000           | 90                  | 0.8400                                        | 0.6220                           | 4.8857          | 3.0389                      | 0.0000 |
| 19.0                 | 0                     | 0.0000           | 88                  | 0.8800                                        | 0.5290                           | 4.9390          | 2.6128                      | 0.0000 |
| 19.5                 | 0                     | 0.0000           | 89                  | 0.8900                                        | 0.5000                           | 4.9524          | 2.4762                      | 0.0000 |
| 20.0                 | 0                     | 0.0000           | 90                  | 0.9300                                        | 0.4180                           | 5.0057          | 2.0924                      | 0.0000 |

## Subject 4, Test 5

| Equation Type | Equation                                            | Equation Parameters |        |       |         |
|---------------|-----------------------------------------------------|---------------------|--------|-------|---------|
| regression    | $X1 = -1/D (\alpha \cdot X2 + (1-\alpha) \cdot X3)$ | D=                  | 0.33   | alfa= | 0.60    |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X1 + X2 = X3 + X4$                                 |                     |        |       |         |
| regression    | $X4 = -1/D (\alpha \cdot X6 + (1-\alpha) \cdot X7)$ | D=                  | 0.76   | alfa= | 0.21    |
| gain          | $X4 = \text{Coef} \cdot X5 + C$                     | Coef =              | 0.0343 | C =   | -2.2578 |
| i/t           |                                                     |                     |        |       |         |
| balance       | $X4 + X6 = X7 + X8$                                 |                     |        |       |         |
| gain          | $X9 = Y \cdot X8$                                   | Y =                 | 4.8864 |       |         |
| balance       | $X9 = X10 + X11 + X12$                              |                     |        |       |         |
| exogenous     |                                                     |                     |        |       |         |
| regression    | $X10 = \text{Eff} \cdot X11$                        | Eff =               | 0.0348 |       |         |
| exogenous     | $X12 = \text{RM}$                                   | RM =                | 2.1001 |       |         |

|   |        |        |    |       |         |         |       |    |    |       |   |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|----|-------|---|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.27632 | 1.03947 | 0     | 0  | 0  | 0     | 0 | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.034 | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X5  | = | 2.2578  |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0  | 0     | 0 | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | -1    | 0  | 0  | 0     | 0 | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.886 | -1 | 0  | 0     | 0 | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1  | 1     | 1 | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 1  | 0     | 0 | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | -1 | 0.035 | 0 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0  | 0     | 0 | 1 | X12 | = | 2.10011 |     |



Subject 4, Task 5, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.55 | -0.19 | -0.17 | 0.53 | 81.24  | -0.48 | -0.38 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 1.00  | 0.49 | -0.17 | -0.15 | 0.46 | 79.38  | -0.38 | -0.35 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 2.00  | 0.44 | -0.15 | -0.15 | 0.44 | 78.72  | -0.35 | -0.33 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 3.00  | 0.44 | -0.15 | -0.14 | 0.43 | 78.48  | -0.33 | -0.33 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 4.00  | 0.59 | -0.14 | -0.27 | 0.72 | 86.83  | -0.33 | -0.61 | 1.00 | 4.87 | 0.09 | 2.68 | 2.10 |
| 5.00  | 0.87 | -0.27 | -0.31 | 0.90 | 92.03  | -0.61 | -0.70 | 1.00 | 4.87 | 0.09 | 2.68 | 2.10 |
| 6.00  | 0.95 | -0.31 | -0.32 | 0.96 | 93.88  | -0.70 | -0.74 | 1.00 | 4.87 | 0.09 | 2.68 | 2.10 |
| 7.00  | 0.91 | -0.32 | -0.27 | 0.85 | 90.60  | -0.74 | -0.62 | 0.73 | 3.58 | 0.05 | 1.43 | 2.10 |
| 8.00  | 0.79 | -0.27 | -0.25 | 0.77 | 88.40  | -0.62 | -0.58 | 0.73 | 3.58 | 0.05 | 1.43 | 2.10 |
| 9.00  | 0.72 | -0.25 | -0.22 | 0.69 | 85.93  | -0.58 | -0.51 | 0.62 | 3.03 | 0.03 | 0.89 | 2.10 |
| 10.00 | 0.65 | -0.22 | -0.21 | 0.64 | 84.60  | -0.51 | -0.48 | 0.62 | 3.03 | 0.03 | 0.89 | 2.10 |
| 11.00 | 0.63 | -0.21 | -0.21 | 0.63 | 84.13  | -0.48 | -0.48 | 0.62 | 3.03 | 0.03 | 0.89 | 2.10 |
| 12.00 | 0.62 | -0.21 | -0.21 | 0.62 | 83.97  | -0.48 | -0.47 | 0.62 | 3.03 | 0.03 | 0.89 | 2.10 |
| 13.00 | 0.62 | -0.21 | -0.20 | 0.62 | 83.91  | -0.47 | -0.47 | 0.62 | 3.03 | 0.03 | 0.89 | 2.10 |
| 14.00 | 0.57 | -0.20 | -0.16 | 0.52 | 81.07  | -0.47 | -0.38 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 15.00 | 0.73 | -0.16 | -0.36 | 0.93 | 92.80  | -0.38 | -0.79 | 1.34 | 6.53 | 0.15 | 4.29 | 2.10 |
| 16.00 | 1.14 | -0.36 | -0.41 | 1.19 | 100.55 | -0.79 | -0.94 | 1.34 | 6.53 | 0.15 | 4.29 | 2.10 |
| 17.00 | 1.26 | -0.41 | -0.43 | 1.29 | 103.30 | -0.94 | -0.99 | 1.34 | 6.53 | 0.15 | 4.29 | 2.10 |
| 18.00 | 1.06 | -0.43 | -0.23 | 0.86 | 90.79  | -0.99 | -0.56 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 19.00 | 0.63 | -0.23 | -0.18 | 0.58 | 82.77  | -0.56 | -0.41 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |
| 20.00 | 0.51 | -0.18 | -0.15 | 0.48 | 79.92  | -0.41 | -0.36 | 0.43 | 2.10 | 0.00 | 0.00 | 2.10 |

Subject 5, Task 5, experimentally collected data

| Time<br>min. | Work<br>Watts | Work<br>Kcal/min | HR<br>B/min | RQ<br>CO2/O2 | VO2<br>l/min | Yield<br>Kcal/l | VO2<br>Kcal/min | Eff    |
|--------------|---------------|------------------|-------------|--------------|--------------|-----------------|-----------------|--------|
| ****         | ****          |                  | ****        | ****         | ****         |                 |                 |        |
| 0.5          | 0             | 0.0000           | 86          | 0.8500       | 0.3280       | 4.8991          | 1.6069          | 0.0000 |
| 1.0          | 0             | 0.0000           | 87          | 0.8600       | 0.3090       | 4.9124          | 1.5179          | 0.0000 |
| 1.5          | 0             | 0.0000           | 86          | 0.8300       | 0.4700       | 4.8724          | 2.2900          | 0.0000 |
| 2.0          | 0             | 0.0000           | 82          | 0.8500       | 0.3400       | 4.8991          | 1.6657          | 0.0000 |
| 2.5          | 0             | 0.0000           | 84          | 0.8700       | 0.2800       | 4.9257          | 1.3792          | 0.0000 |
| 3.0          | 0             | 0.0000           | 85          | 0.8600       | 0.2890       | 4.9124          | 1.4197          | 0.0000 |
| 3.5          | 7             | 0.0931           | 89          | 0.9300       | 0.4920       | 5.0057          | 2.4628          | 0.1469 |
| 4.0          | 7             | 0.0931           | 102         | 0.8800       | 0.4630       | 4.9390          | 2.2868          | 0.2033 |
| 4.5          | 7             | 0.0931           | 99          | 0.8300       | 0.5830       | 4.8724          | 2.8406          | 0.0920 |
| 5.0          | 7             | 0.0931           | 103         | 0.7900       | 0.5780       | 4.8191          | 2.7854          | 0.0973 |
| 5.5          | 7             | 0.0931           | 101         | 0.7800       | 0.6800       | 4.8057          | 3.2679          | 0.0647 |
| 6.0          | 7             | 0.0931           | 102         | 0.8100       | 0.5570       | 4.8457          | 2.6991          | 0.1070 |
| 6.5          | 3             | 0.0497           | 94          | 0.7900       | 0.5740       | 4.8191          | 2.7661          | 0.0507 |
| 7.0          | 3             | 0.0497           | 92          | 0.8000       | 0.4680       | 4.8324          | 2.2616          | 0.1044 |
| 7.5          | 3             | 0.0497           | 90          | 0.8100       | 0.4840       | 4.8457          | 2.3453          | 0.0888 |
| 8.0          | 3             | 0.0497           | 92          | 0.8200       | 0.4880       | 4.8591          | 2.3712          | 0.0848 |
| 8.5          | 2             | 0.0311           | 101         | 0.8100       | 0.5410       | 4.8457          | 2.6215          | 0.0364 |
| 9.0          | 2             | 0.0311           | 97          | 0.8100       | 0.6150       | 4.8457          | 2.9801          | 0.0256 |
| 9.5          | 2             | 0.0311           | 103         | 0.8300       | 0.5550       | 4.8724          | 2.7042          | 0.0332 |
| 10.0         | 2             | 0.0311           | 101         | 0.8600       | 0.4340       | 4.9124          | 2.1320          | 0.0851 |
| 10.5         | 2             | 0.0311           | 95          | 0.8400       | 0.5240       | 4.8857          | 2.5601          | 0.0392 |
| 11.0         | 2             | 0.0311           | 102         | 0.8200       | 0.4990       | 4.8591          | 2.4247          | 0.0472 |
| 11.5         | 2             | 0.0311           | 99          | 0.8400       | 0.6420       | 4.8857          | 3.1366          | 0.0227 |
| 12.0         | 2             | 0.0311           | 101         | 0.8300       | 0.5010       | 4.8724          | 2.4411          | 0.0461 |
| 12.5         | 2             | 0.0311           | 100         | 0.8200       | 0.5810       | 4.8591          | 2.8231          | 0.0294 |
| 13.0         | 2             | 0.0311           | 94          | 0.8500       | 0.5160       | 4.8991          | 2.5279          | 0.0408 |
| 13.5         | 0             | 0.0000           | 87          | 0.8200       | 0.7200       | 4.8591          | 3.4985          | 0.0000 |
| 14.0         | 0             | 0.0000           | 83          | 0.8000       | 0.5080       | 4.8324          | 2.4549          | 0.0000 |
| 14.5         | 10            | 0.1490           | 94          | 0.8300       | 0.4550       | 4.8724          | 2.2169          | 0.4482 |
| 15.0         | 10            | 0.1490           | 108         | 0.8100       | 0.5930       | 4.8457          | 2.8735          | 0.1507 |
| 15.5         | 10            | 0.1490           | 102         | 0.8100       | 0.5760       | 4.8457          | 2.7911          | 0.1644 |
| 16.0         | 10            | 0.1490           | 107         | 0.7900       | 0.5840       | 4.8191          | 2.8143          | 0.1603 |
| 16.5         | 10            | 0.1490           | 100         | 0.8300       | 0.7190       | 4.8724          | 3.5032          | 0.0921 |
| 17.0         | 10            | 0.1490           | 98          | 0.8200       | 0.6960       | 4.8591          | 3.3819          | 0.0995 |
| 17.5         | 0             | 0.0000           | 90          | 0.8300       | 0.7480       | 4.8724          | 3.6445          | 0.0000 |
| 18.0         | 0             | 0.0000           | 81          | 0.8700       | 0.6260       | 4.9257          | 3.0835          | 0.0000 |
| 18.5         | 0             | 0.0000           | 85          | 0.9100       | 0.4230       | 4.9790          | 2.1061          | 0.0000 |
| 19.0         | 0             | 0.0000           | 79          | 0.9000       | 0.4340       | 4.9657          | 2.1551          | 0.0000 |
| 19.5         | 0             | 0.0000           | 75          | 0.9300       | 0.3040       | 5.0057          | 1.5217          | 0.0000 |
| 20.0         | 0             | 0.0000           | 79          | 0.9700       | 0.2660       | 5.0590          | 1.3457          | 0.0000 |



## Subject 5, Test 5

| Equation Type | Equation                                    | Equation Parameters |        |             |
|---------------|---------------------------------------------|---------------------|--------|-------------|
| regression    | $X1 = -1/D (\alpha * X2 + (1-\alpha) * X3)$ | D=                  | 0.33   | alfa= 0.60  |
| i/t           |                                             |                     |        |             |
| balance       | $X1 + X2 = X3 + X4$                         |                     |        |             |
| regression    | $X4 = -1/D (\alpha * X6 + (1-\alpha) * X7)$ | D=                  | 0.76   | alfa= 0.21  |
| gain          | $X4 = \text{Coef} * X5 + C$                 | Coef =              | 0.0287 | C = -2.4770 |
| i/t           |                                             |                     |        |             |
| balance       | $X4 + X6 = X7 + X8$                         |                     |        |             |
| gain          | $X9 = Y * X8$                               | Y =                 | 4.8854 |             |
| balance       | $X9 = X10 + X11 + X12$                      |                     |        |             |
| exogenous     |                                             |                     |        |             |
| regression    | $X10 = \text{Eff} * X11$                    | Eff =               | 0.0746 |             |
| exogenous     | $X12 = \text{RM}$                           | RM =                | 1.7354 |             |

|   |        |        |    |       |         |         |       |    |   |    |       |   |     |   |         |     |
|---|--------|--------|----|-------|---------|---------|-------|----|---|----|-------|---|-----|---|---------|-----|
| 1 | 1.8182 | 1.2121 | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X1  | = | 0       |     |
| 0 | 1      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X2  | = | -0.19   | i/t |
| 1 | 1      | -1     | -1 | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X3  | = | 0       |     |
| 0 | 0      | 0      | 1  | 0     | 0.27632 | 1.03947 | 0     | 0  | 0 | 0  | 0     | 0 | X4  | = | 0       |     |
| 0 | 0      | 0      | -1 | 0.029 | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X5  | = | 2.477   |     |
| 0 | 0      | 0      | 0  | 0     | 1       | 0       | 0     | 0  | 0 | 0  | 0     | 0 | X6  | = | -0.48   | i/t |
| 0 | 0      | 0      | 1  | 0     | 1       | -1      | -1    | 0  | 0 | 0  | 0     | 0 | X7  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 4.885 | -1 | 0 | 0  | 0     | 0 | X8  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | -1 | 1 | 1  | 1     | 1 | X9  | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 1  | 0     | 0 | X10 | = | 0       | ex  |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | -1 | 0.075 | 0 | X11 | = | 0       |     |
| 0 | 0      | 0      | 0  | 0     | 0       | 0       | 0     | 0  | 0 | 0  | 0     | 1 | X12 | = | 1.73541 |     |

Subject 5, Task 5, model solution

| Time  | X1   | X2    | X3    | X4   | X5     | X6    | X7    | X8   | X9   | X10  | X11  | X12  |
|-------|------|-------|-------|------|--------|-------|-------|------|------|------|------|------|
| 0.00  | 0.00 | 0.00  | 0.00  | 0.00 | 0.00   | 0.00  | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.00  | 0.53 | -0.19 | -0.15 | 0.49 | 103.41 | -0.48 | -0.34 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 1.00  | 0.43 | -0.15 | -0.13 | 0.40 | 100.36 | -0.34 | -0.30 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 2.00  | 0.38 | -0.13 | -0.12 | 0.37 | 99.28  | -0.30 | -0.28 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 3.00  | 0.36 | -0.12 | -0.12 | 0.36 | 98.89  | -0.28 | -0.27 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 4.00  | 0.43 | -0.12 | -0.18 | 0.50 | 103.64 | -0.27 | -0.41 | 0.63 | 3.08 | 0.09 | 1.25 | 1.74 |
| 5.00  | 0.57 | -0.18 | -0.20 | 0.58 | 106.62 | -0.41 | -0.45 | 0.63 | 3.08 | 0.09 | 1.25 | 1.74 |
| 6.00  | 0.61 | -0.20 | -0.20 | 0.61 | 107.67 | -0.45 | -0.47 | 0.63 | 3.08 | 0.09 | 1.25 | 1.74 |
| 7.00  | 0.59 | -0.20 | -0.18 | 0.56 | 105.77 | -0.47 | -0.41 | 0.50 | 2.45 | 0.05 | 0.67 | 1.74 |
| 8.00  | 0.53 | -0.18 | -0.17 | 0.52 | 104.50 | -0.41 | -0.39 | 0.50 | 2.45 | 0.05 | 0.67 | 1.74 |
| 9.00  | 0.50 | -0.17 | -0.15 | 0.48 | 103.07 | -0.39 | -0.36 | 0.45 | 2.18 | 0.03 | 0.42 | 1.74 |
| 10.00 | 0.46 | -0.15 | -0.15 | 0.46 | 102.30 | -0.36 | -0.35 | 0.45 | 2.18 | 0.03 | 0.42 | 1.74 |
| 11.00 | 0.45 | -0.15 | -0.15 | 0.45 | 102.03 | -0.35 | -0.34 | 0.45 | 2.18 | 0.03 | 0.42 | 1.74 |
| 12.00 | 0.45 | -0.15 | -0.15 | 0.45 | 101.93 | -0.34 | -0.34 | 0.45 | 2.18 | 0.03 | 0.42 | 1.74 |
| 13.00 | 0.45 | -0.15 | -0.15 | 0.45 | 101.90 | -0.34 | -0.34 | 0.45 | 2.18 | 0.03 | 0.42 | 1.74 |
| 14.00 | 0.42 | -0.15 | -0.13 | 0.40 | 100.26 | -0.34 | -0.29 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 15.00 | 0.50 | -0.13 | -0.22 | 0.60 | 107.05 | -0.29 | -0.49 | 0.79 | 3.88 | 0.15 | 2.00 | 1.74 |
| 16.00 | 0.70 | -0.22 | -0.25 | 0.72 | 111.53 | -0.49 | -0.57 | 0.79 | 3.88 | 0.15 | 2.00 | 1.74 |
| 17.00 | 0.76 | -0.25 | -0.26 | 0.77 | 113.12 | -0.57 | -0.59 | 0.79 | 3.88 | 0.15 | 2.00 | 1.74 |
| 18.00 | 0.66 | -0.26 | -0.16 | 0.56 | 105.88 | -0.59 | -0.38 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 19.00 | 0.45 | -0.16 | -0.13 | 0.43 | 101.24 | -0.38 | -0.31 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |
| 20.00 | 0.39 | -0.13 | -0.12 | 0.38 | 99.59  | -0.31 | -0.28 | 0.36 | 1.74 | 0.00 | 0.00 | 1.74 |

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