Dietary influences on selected physiological parameters in collegiate wrestlers during the pre-competitive training period
by Don Wayne Jensen

A thesis submitted in partial fulfillment of the requirements for the degree of . Master of Science in Physical Education
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Abstract:
The purpose of this investigation was to examine the relationship between the presence and absence of specific nutritional control for purposes of attaining a pre-selected weight loss and 31 physiological parameters in 18 collegiate wrestlers during the pre-competitive training period utilizing a pre- and post-test design.

The subjects were divided into two groups. An experimental group (EG) was placed on a high carbohydrate-hypocaloric diet. The second group (CG) served as controls and received no dietary directions to aid in reducing body weight.

As a result of following a hypocaloric diet, the EG experienced a significantly larger ($P<0.05$) reduction in total body weight in comparison to the CG. The composition of the weight loss for the EG was made up of a decrease in both fat weight and lean body weight. The CG had an overall decrease in total body weight due to a decrease in fat weight partly offset by an increase in lean body weight, however, the two groups for body composition were not significant. No significant differences were observed for muscular endurance, power, and aerobic endurance, although results indicate that the EG made slightly larger improvements for nearly every variable measured over the pre-competitive training period. Also, at both weigh-in periods just prior to competition, the differences found in the urinary profiles (dehydration/ rehydration) between the two groups were not significant.

The results of this study indicate that there may be an individual optimal body composition for each wrestler and that attempts at weight reduction beyond that level would be at the expense of lean body weight as well as fat weight. Gains in performance related variables appear to be slight as a result of following a hypocaloric diet."

DIETARY INFLUENCES ON SELECTED PHYSIOLOGICAL PARAMETERS IN COLLEGIATE WRESTLERS DURING THE PRE-COMPETITIVE TRAINING PERIOD

by

Don Wayne Jensen

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Don Wayne Jensen

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The purpose of this investigation was to examine the relationship between the presence and absence of specific nutritional control for purposes of attaining a pre-selected weight loss and 31 physiological parameters in 18 collegiate wrestlers during the pre-competitive training period utilizing a pre- and post-test design.

The subjects were divided into two groups. An experimental group (EG) was placed on a high carbohydrate-hypocaloric diet. The second group (CG) served as controls and received no dietary directions to aid in reducing body weight.

As a result of following a hypocaloric diet, the EG experienced a significantly larger ($P<0.05$) reduction in total body weight in comparison to the CG. The composition of the weight loss for the EG was made up of a decrease in both fat weight and lean body weight. The CG had an overall decrease in total body weight due to a decrease in fat weight partly offset by an increase in lean body weight, however, the two groups for body composition were not significant. No significant differences were observed for muscular endurance, power, and aerobic endurance, although results indicate that the EG made slightly larger improvements for nearly every variable measured over the pre-competitive training period. Also, at both weigh-in periods just prior to competition, the differences found in the urinary profiles (dehydration/rehydration) between the two groups were not significant.

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CHAPTER I

THE PROBLEM

Introduction

In the sport of wrestling, contestants are grouped into weight classes to allow them to compete with others of a similar body weight. In an effort to maximize performance potential, wrestlers often attempt to minimize the amount of body fat, as fat does not contribute to performance. By reducing to their lowest functional body weight the wrestler hopes to gain an advantage over opponents having more body fat and less muscle mass.

Mental attitude, technique, muscular strength, cardiovascular endurance, body composition, and energy levels are among the many factors which influence the overall performance of wrestlers. In addition, semi-starvation plus dehydration are often used to attain an artificially low body weight to qualify for a lower weight class. Whenever possible, the negative effects of "making weight" prior to each contest through dieting and dehydration should be kept to a minimum because an artificially low body weight may significantly curtail the progress of wrestlers as they can neither train nor compete at their optimal level (4, 5, 6, 27, 53). To minimize the stresses caused by chronic caloric restriction and dehydration, any major changes in body weight to achieve an "optimal" body composition would most appropriately take place during the base- and pre-competitive training periods. A need exists for research to determine if a high carbohydrate-hypocaloric diet will assist wrestlers attain their optimal body composition during the pre-competitive training period.

Statement of the Problem

The purpose of this investigation is to examine changes in body composition, total body weight, girths, muscular endurance, power, and aerobic endurance that occur during a collegiate wrestling pre-competitive training period in wrestlers following a program of prescribed dietary controls versus a free or uncontrolled dietary program.

Specific Objectives

1. To analyze the composition of foods consumed from food items and portion size for each subject during the pre-competitive training period.

2. To measure the changes in body composition, total body weight, and girths for each subject during the pre-competitive training period.

3. To measure the changes in muscular endurance, power, and aerobic endurance for each subject during the pre-competitive training period.

4. To measure the specific gravity of urine samples from each of the subjects the morning of the first competition (weigh-ins) and again five hours later.

Hypothesis

Null Hypothesis. It was hypothesized that there would be no significant difference between the experimental and control groups in body composition, total body weight, girths, muscular endurance, power, and aerobic endurance during the pre-competitive training period as a result of dietary controls.

Alternate Hypothesis. It was hypothesized that there would be a significant difference between the experimental and control groups in body composition, total body weight, girths, muscular endurance, power, and aerobic endurance during the pre-competitive training period as a result of dietary controls.

Delimitations

This study was delimited to twenty-five members of the Montana State University (MSU) wrestling team, 1983-84.

Limitations

1. The selection of the subjects for the experimental and control groups were based on their campus living arrangements.

2. The degree of weight reduction was limited to the amount required for each subject to reach a specified weight classification (pre-determined by each subject) for competition.

3. The experimental group's dietary intake and food selection was not completely controlled, as the subjects could not be continuously observed during the investigation.

4. Records of food intake (i.e., portion size, ingredients) by both groups were assumed to be accurate.

5. The ability of the investigator to accurately analyze the recorded food intake of the subjects was assumed to be accurate.

6. The analysis of the subjects' diets was performed on an N-Squared Nutritionist computer program, which had a limited number of listings in the food code.

7. All of the test results are assumed to represent maximal efforts on the part of the subjects.

8. The training and testing of the subjects may be affected by injury and/or illness.

General Terms and Definitions

1. Aerobic Endurance. Aerobic endurance refers to cardiovascular fitness, which is a more general total body endurance and is not localized to any specific muscle group (63).

2. Aerobic Training. Aerobic training refers to training which can be performed with a sufficient supply of oxygen available to meet the activities' energy demands (63).

3. Anaerobic Training. Anaerobic training refers to training involving intense periods of exercise such as wrestling or interval training (63).

4. Base-Training Period. During the base-training period emphasis is placed upon building overall strength, increasing aerobic endurance, rehabilitating injuries, promoting general flexibility, and gradually

reducing total body weight nearer to competitive weight. This period extends from April 15 to September 29.

5. Carbohydrate. Carbohydrate refers to a food substance that includes various sugars and starches and is found in the body in the form of glucose and glycogen (63).

6. Competitive Training Period. During the competitive training period the emphasis is upon maintaining the strength and aerobic endurance levels built during the base- and pre-competitive training periods, progressively increasing the intensity of wrestling, and adding interval training (fartleks, sprints, and stair running). This period extends from November 18 to March 15.

7. Dehydration. Dehydration refers to an extreme decrease of the intake of fluids in an attempt to rapidly reduce body weight.

8. Diet. Diet refers to foods consumed to meet nutritional needs. It is also used to describe the pattern of foods selected to meet these needs, as well as a program to lose, maintain, or gain weight (63).

9. Fat. Fat refers to a food substance that is composed of glycerol and fatty acids (63).

10. Memory Recall. Memory recall refers to an interview with a subject to determine food intake and portion sizes for a given time period (36).

11. Muscular Endurance. Muscular endurance refers to the muscles' ability to resist fatigue and perform physical work (repetitious) with a given percentage of the subject's body weight.

12. Power. For the purposes of this investigation, power refers to the maximal amount of work which can be performed for a given resistance

and time period. This is a reflection of anaerobic power as well as anaerobic metabolism (31).

13. Pre-Competitive Training Period. During the pre-competitive training period the emphasis is to continue building the aerobic base, change from a general strength training program to one designed specifically for wrestling, progressively add more wrestling time and reduce body weight nearer to competitive weight. This period extends from October 1 to November 17.

14. Protein. Protein refers to a food substance formed from amino acids (63).

15. Semi-Starvation. Semi-starvation refers to the practice of severely restricting caloric intake in an attempt to induce a reduction in body weight.

16. Specific Gravity. Specific gravity is the weight of a substance compared with the weight of an equal amount of some other substance taken as a standard. The standard for liquids is usually water, which has a specific gravity of 1.000. If a urine sample shows a specific gravity of 1.020, this means the urine is 1.020 times heavier than an equal volume of water. Normal urine has a range of 1.006 to 1.025 (41).

CHAPTER II

REVIEW OF RELATED LITERATURE

The focal point of this investigation is directed towards the physiological effects of weight reduction in collegiate wrestlers as a result of dietary controls. Though a great deal of information is available which relates to performance in the sport of wrestling, relatively little research has examined performance changes as a function of dietary restriction (26, 62). This chapter attempts to provide a brief summary of such research and will be structured in the following manner:

1. Physical Characteristics of Wrestlers
2. Dietary Controls on Weight Loss in Wrestlers
3. Dehydration in Wrestlers
4. Dehydration/Rehydration in Wrestlers
5. Acute and Chronic Semi-Starvation

Physical Characteristics of Wrestlers

Regardless of variations in anatomic structure, successful wrestlers are characterized by low levels of body fat, except for those participating in the heavyweight division. Excessive body fat acts as deadweight and reduces performance potential (63). Of greater concern is the fact that wrestlers are grouped into weight classes, consequently they may have to compete against others having a larger percentage of their body weight as muscle if the individual wrestler is overly fat. Having more lean tissue can be viewed as a definite advantage in a combative sport such as wrestling where strength is major determinant in the outcome.

Gayle and Flynn (24) studied nineteen wrestlers participating in the 1974 U.S. Olympic Trials to determine the maximal oxygen consumption and the relative body fat of high-ability wrestlers. The subjects ranged from 17 to 36 years old and weighed from 52 to 135 kg. Results indicated the mean estimated body fat was 9.8 percent for all but the heavyweight wrestlers (27.5%) who attempt to gain as much weight as possible.

Di Prampero and co-workers (21) investigated 116 athletes participating in the 1968 Olympic Games in Mexico City. They reported pentathletes as having the lowest percentage of body fat (10%), followed by long distance runners (11%), middle distance runners (11.5%), cyclists (11.5%), boxers (12%), wrestlers (12.5%), swimmers (12.%), sprint runners (12.5%), rowers (14%), soccer players (14%), fencers (14.5%), and rifle shooters (24.5%).

Tcheng and Tipton (57) undertook the assessment of anthropometric data on 582 state finalists and 835 "average" Iowa high school wrestlers to develop a multiple regression equation to predict minimal wrestling weight (MWW). Measurements were taken for height, weight, diameters, girths, and skinfolds. As a result of their findings, the recommended minimal level of body fat without prior medical approval was estimated at five percent.

Table 1 presents a summary of selected body composition studies performed on wrestlers and non-athletes (normals). From these studies it is apparent that, as a group, wrestlers tend to be lean. It appears that the optimal level of relative body fat for wrestlers is approximately six to nine percent, with five percent the recommended minimum. Some individuals may be able to safely maintain health when reducing below a level of five percent body fat (62).

Dietary Control on Weight Loss in Wrestlers

An in-depth case study was performed by Widerman and Hagan (62) on one wrestler (54.9 kg) preparing for the 1981 Maccabiah Games Trials and the National AAU Championships. The subject remained on a high carbohydrate-low calorie diet for the duration of the study (Feb. 23-Apr. 13, 1981). The total amount of Kcal/week was recorded and averaged to determine the Kcal consumed per day. From February 23 to March 17, the average caloric intake was approximately 2006 Kcal/day, with the proportion of foodstuffs being approximately 61 percent carbohydrate, 19 percent fat, and 20 percent protein. From March 23 to April 13, his average caloric consumption was 1152 Kcal/day, with a resultant change in the proportion of foodstuffs to 63 percent carbohydrate, 12 percent fat, and 25 percent protein.

Anthropometric measurements, muscular strength, maximal aerobic capacity, pulmonary function, and blood tests were performed during three testing sessions (Feb. 23, Mar. 16, and Apr. 13). A summary of results found: (a) maximal aerobic capacity (VO_2 max), as determined using the Balke treadmill test, increased by 2.0 percent when expressed

Table 1. Body Composition of Male Normals and Athletes.

Investigator	No. of Subjects	Age	Subjects	% Fat	Skinfolds* TR	TH	CH	AB	SU	SI
Katch and Michael (33)	94	15-18	High school wrestlers	6.9	9.0	--	7.1	12.9	10.5	12.9
Tcheng and Tipton (57)	582	15-18	High school wrestlers	--	7.7	7.7	4.5	8.6	6.5	9.1
Kelly et al. (34)	13	18-22	Collegiate wrestlers	10.4	6.8	10.5	8.1	12.7	10.5	12.2
Sinning (50)	35	18-22	Collegiate wrestlers	8.8	8.9	--	--	9.4	9.5	--
Wilmore and Behnke (64)	135	--	College-aged male normals	14.6	7.9	14.9	--	16.0	14.1	19.3
Jackson and Pollock (30)	95	18-22	College-aged male normals	13.4	13.6	17.4	11.4	20.6	13.9	15.2

in oxygen consumption per minute per kilogram of body weight; (b) $\dot{V}O_2$ max, when expressed in terms of oxygen consumption per minute, decreased by 5.8 percent; (c) total skinfolds (seven sites) were observed to decrease from 43mm to 30mm, with a concomitant reduction in body fat from 4.8 to 1.1 percent; (d) total body weight decreased from 54.9 to 50.6 kg; (e) isotonic muscular strength was maintained for both the bench and leg press; however, when expressed in relation to body weight, there was an 8.7 and 8.6 percent increase, respectively. Explosive power increased by 25 percent on the isokinetic bench press and 5.6 percent on the isokinetic leg press; (f) blood test results indicated that all plasma constituents remained in the normal range; (g) electrolyte balance remained unchanged; (h) triglyceride levels remained constant, though as body weight decreased, the ratio of LDL-to-HDL was observed to decrease, and cholesterol-to-HDL ratio also decreased due to increased HDL values. Within the limitations of this investigation, results indicate that a highly trained wrestler was able to drop two weight classifications by reducing his weight through semi-starvation and dehydration methods while maintaining or even improving his fitness level.

In a similar study, Hansen (26) investigated the effects of dietary controls on four wrestlers and four non-wrestlers over a three-week period. The subjects reduced approximately 5.3 to 8.8 percent of their body weight during the course of the investigation. The caloric content of the reduction diet equaled 10 Kcal per pound of the desired weight (i.e., a subject reducing to 142 pounds consumed approximately 1420 Kcal per day). Test batteries of physiologic variables were performed prior to the initiation of the diet (control period) and each week thereafter. Measurements of oxygen consumption, blood lactic acid levels, heart rate and rectal temperatures were recorded at each testing session. The results indicated that: (a) $\dot{V}O_2$ max, as measured on a bicycle ergometer at an established workload, showed no significant decrease when expressed in oxygen consumption per minute per kilogram of body weight ($ml \cdot min^{-1} \cdot kg^{-1}$); (b) $\dot{V}O_2$ max expressed in liters per minute ($l\ min^{-1}$) decreased; (c) anaerobic work, determined from blood lactate levels, was observed to increase in concentration by the end of the study (though work performance was not impaired), indicating that the work was becoming more anaerobic; (d) heart rate and body temperature during exercise were not significantly elevated as a result of the weight reduction. From the results it was concluded that gradual weight reduction through dietary means does not significantly impair performance for the variables measured.

Dehydration in Wrestlers

Empirical evidence, as well as the findings of various investigators, indicates the practice of rapid weight reduction (RWR) is widespread through all levels of amateur wrestling (25, 34, 57-59, 66, 67). Bock (11) estimated that perhaps as high as ninety percent of all wrestlers use some form of RWR in order to qualify for a specific weight classification. Up to ten pounds of body weight may be lost to "make weight" (34). Repeated use of the regimen may take place as many as twenty-five times a season (66). RWR is most commonly brought about through semi-starvation, exercise and/or dehydration, with dehydration being responsible for the largest weight loss. Layered clothings, nylon or rubber sweat suits, sauna and steam baths are the primary methods of thermal dehydration. The use of dehydration generally occurs within a forty-eight hour period prior to weigh-ins (34, 62, 67).

Tipton and Tcheng (59) studied 747 high school wrestlers from Iowa and found that most wrestlers lost approximately five percent of their body weight in preparation for weight certification.* Changes in body weight were measured over a seventeen-day period with most of the changes taking place in the final ten days. It was concluded that weight reduction was brought about primarily through dehydration and semi-starvation.

A longitudinal study was conducted by Zambreski and co-workers (67) on eleven members of the 1974-75 NCAA championship team from the University of Iowa to determine if the practice of RWR was used as extensively as had been found at the high school level. Results indicated that dehydration was the principal method by which wrestlers reduced weight. As a group, they regularly lost approximately six percent of their total body weight at periodic intervals (competition) throughout the season.)

The effects of RWR upon the physical working capacity (PWC) of wrestlers is a controversial subject. Both the American Medical Association (4, 5) and the American College of Sports Medicine (6) have taken the position that the practice of RWR is a potential health

* High school wrestlers are required to be certified by a physician at the beginning of the wrestling season to determine the minimum weight classification in which they can participate.

hazard and that measures must be taken to eliminate the abuses associated with "making weight." The respective position statements of the AMA and ACSM are based upon the research of Adolph (1), Saltin (45) and others, whose findings have indicated that not only is PWC significantly impaired but as the extent of dehydration increases so does the risk to one's health (Table 2). Adolph (1) stated the following in regards to the relative effects of dehydration on man:

> "We know that man tolerates water deficits of up to 3 to 4 percent of body weight with moderate impairment of efficiency; at 5 to 8 percent deficits, the average man in the desert is fatigued, spiritless, prone to complain about his situation, and predisposed to physical collapse. Cooperation among men dehydrated more than 10 percent of their weights is not to be expected. Even after man's working or fighting abilities have succumbed to dehydration, he can survive some additional loss of body water, and recovery is still possible. Accurate observations on man do not extend to deficits greater than 11 percent of body weight. . . . Our best estimate of the rapid dehydration which is limiting for man is 20 percent loss of body weight."

Dehydration/Rehydration in Wrestlers

Since most of the criticism of weight reduction practices is directed towards performance in the dehydrated state, such a position may not be entirely justified if, for a given recovery period, rehydration takes place and PWC is restored. A substantial amount of research supports the viewpoint that weight losses of up to seven percent do not significantly impair performance if followed by rehydration prior to performance.

Tuttle (60) investigated the effects of withholding food and water and inducing weight loss through RWR methods on the physiologic responses of thirteen college wrestlers. The subjects were tested at

Table 2. Dehydration in Man (Adolph, 1950).

Water Loss (%)	
0	
	Thirst.
2	Stronger thirst, vague discomfort and sense of oppression, loss of appetite.
	Increasing hemoconcentration.
4	Economy of movement.
	Lagging pace, flushed skin, impatience; in some, weariness and sleepiness, apathy; nausea, emotional instability.
6	Tingling in arms, hands, and feet; heat oppression, stumbling, headache; fit men suffer heat exhaustion; increase in body temperature, pulse rate and respiratory rate.
	Labored breathing, dizziness, cyanosis.
8	Indistinct speech.
	Increasing weakness, mental confusion.
10	Spastic muscles; positive Romberg sign (inability to balance with eyes closed); general incapacity.
	Delirium and wakefulness; swollen tongue.
	Circulatory insufficiency; marked hemoconcentration and decreased blood volume; failed renal function.
	Shriveled skin; inability to swallow.
15	Dim vision.
	Sunken eyes, painful urination.
	Deafness; numb skin; shriveled tongue.
	Stiffened eyelids.
	Cracked skin; cessation of urine formation.
20	Bare survival limit.
	Death

five different times in the dehydrated state and then retested following rehydration. Of the initial test group, only five subjects completed the entire experiment. Eighteen measurements of neuromuscular, cardiovascular and respiratory functioning were determined. The degree of weight loss observed varied from six to ten pounds, representing a decrease in total body weight of 3.6 to 4.9 percent. No statistically significant differences between the testing periods were found for any of the physiologic responses tested, except for a slight increase in heart rate, and a slight decrease in vital capacity in the dehydrated state. It was concluded that a weight reduction of up to five percent of total body weight through RWR had no significant effect on the physiologic responses tested.

An investigation was undertaken by Edwards (23) to determine the effects of short-term semi-starvation and dehydration on the physiologic responses of three college wrestlers. A fourth subject served as the control and was not required to lose weight. Muscular strength was determined by pushups, pullups, and a hand dynamometer. Cardiovascular endurance was tested on a motor-driven treadmill. Measurements for heart rates, blood pressure, blood lactate, and basal metabolism were also made. The subjects were tested prior to initiating rapid weight reduction, again four days later, and the final tests were performed at the end of the seven-day test period. The three subjects had a mean weight loss of approximately six percent of total body weight. The authors concluded that, for the subjects who reduced weight, endurance was the only factor which was significantly negatively affected by the week of semi-starvation and dehydration.

Bowers (16) attempted to discern the effects of RWR on the physiologic responses of high school wrestlers. The subjects were divided into two groups of sixteen. The experimental group was required to use RWR methods in order to compete. The second group served as controls and were not required to lose weight. Five physical efficiency tests were administered to the subjects in each group over a thirteen-week period. Strength was determined by a hand dynamometer; a vertical "chalk jump" was used as a measure of power; endurance was determined using the Pulse Rate Index; the Stepping Stone Test was used as a measure of dynamic balance; and reaction time was determined by an electronic device using a visual signal. Testing was performed each Monday and again the day prior to an interscholastic wrestling meet. No statistically significant differences between the two groups were found for any of the variables measured. This was also the case when a comparison was made using only the experimental group before and after dehydration procedures (prior to competition). It was concluded that a wrestler may safely lose three to four percent of total body weight through RWR methods without adversely affecting physiologic responses.

In a longitudinal study performed by James (32), twenty high school wrestlers were divided into two groups. Ten of the subjects composed the experimental group and were required to periodically (prior to competition) lose weight using RWR methods throughout the wrestling season. The second group served as controls and were not required to lose weight in order to compete. Cardiovascular endurance was determined using the Carlson Fatigue-Curve Test. Testing was performed each week on Mondays (initial practice) and again on Fridays, after the final practice of the week. Comparisons were made for pulse rate, systolic and diastolic blood pressure after interscholastic wrestling matches. The experimental group lost an average of 4.4 to 6.9 percent of their total body weight each week. No significant differences between the two groups were found for any of the variables measured.

Bock (10) tested ten subjects on a university freshman wrestling team to determine the effects of a forty-hour dehydration period on cardiovascular endurance. Maximal oxygen consumption, heart rate, core temperature and exercise weight loss were measured before and after the dehydration period. Fluids were not allowed during the dehydration process. Before final testing the subjects were divided into subgroups of five each. The first group was tested immediately after the dehydration period and the second group was permitted to consume foods and fluids prior to being tested. A statistical analysis comparing the results before and after dehydration indicated that the dehydration process had no significant effect on maximal oxygen consumption. Heart rate and core temperature were not significantly affected by dehydration for the immediately tested group but were elevated following the rehydration period for the group consuming food. Elevated heart rates and core temperatures were partially explained as the result of metabolic action from digestion. Exercise weight loss was significantly affected by the dehydration process; both groups lost significantly more water in the pre-dehydrated condition than in the post-dehydrated condition.

Schuster (47) investigated the effects of RWR on muscular and cardiovascular endurance using twenty college wrestlers divided into experimental and control groups. Each subject in the experimental group was required to lose approximately ten pounds over a seven-day period through semi-starvation and dehydration. The control group was not required to lose weight. Muscular endurance was determined by the number of pushups and squat thrusts the subjects could perform, and cardiovascular endurance was determined by the number of miles they could ride on a bicycle ergometer. In addition, the number of points scored in actual competition were recorded. No significant differences between the two groups were observed for any of the variables measured. It was concluded that conditioned wrestlers can safely lose up to seven percent of their total body weight using RWR methods without adversely affecting performance.

Palmer (38) carried out an investigation on seven men to measure the differences between normal physiologic functioning when performing submaximal work following rapid dehydration and rehydration (five-hour recovery period). The first test was conducted in the evening with the subjects at their normal body weight. The following morning after breakfast, the subjects attempted to lose five percent of their total body weight. Dehydration was brought about by utilizing a steam heated cabinet. The subjects attained a weight reduction of 4.75 percent. Measurements of rectal temperature, exercise and recovery rates, ventilatory rates, ventilatory volume, oxygen consumption, respiratory quotient, oxygen pulse, and ventilatory efficiency were made on the subjects. On the basis of the data collected it was found that: (a) mean temperature changes during and following exercise were not significantly affected between the control period and dehydration/ rehydration; (b) ventilatory volumes, oxygen consumption, respiratory quotient, and respiratory efficiency exhibited no significant changes as a result of dehydration/rehydration; (c) mean exercise heart rate was significantly elevated as a result of dehydration, but returned to normal following rehydration; (d) recovery heart rate increased and was not completely restored following the rehydration period. It was concluded that following a RWR of 4.75 percent of total body weight an impairment in performance will result. If during the rehydration period (five hours) the total amount of water lost is replaced, normal functioning during exercise will occur.

Ribisl and Herbert (44) used eight college wrestlers to determine the effects of dehydration and rehydration upon PWC-170. The test consisted of two consecutive rides on a bicycle ergometer of six minutes duration at submaximal workloads of 450 and 900 kpm/min. The average heart rate during the last two minutes of each ride represented the heart rate for those workloads. PWC-170 was predicted by plotting heart rates against the respective workloads which would result in a heart rate of 170 beats per minute. The subjects were allowed 48 hours in which to reduce their body weight by five percent. The methods employed by the subjects were not reported. A repeat test in the dehydrated state was performed a week later to determine the reliability of the results. From the data collected, it was concluded that PWC-170 decreased significantly but was restored following a five-hour rehydration period.

Kelly and co-workers (34) studied the effects of a competitive wrestling season on the body composition, cardiovascular fitness, muscular strength and endurance in collegiate wrestlers. At the end of the regular season (prior to Nationals), four national qualifiers were asked to simulate preparations for competition by rapidly dehydrating to their respective weight classes for a morning weigh-in, followed by running to exhaustion on a treadmill after a five-hour recovery period (uncontrolled food and fluid intake). The subjects lost approximately 3.7 to 9.5 percent of their total body weight without causing a significant change in aerobic power as measured after recovery.

Although collegiate wrestlers are allowed up to five hours in which to rehydrate following weigh-ins, interscholastic wrestlers in some states are only allowed up to one hour after weigh-ins in which to replace body fluids. Allen and co-workers (3) looked into this situation to determine the extent to which normalization of body water could be reestablished when an unlimited fluid intake was permitted for one hour. Over a 48-hour RWR period, an average weight loss of 4.3 percent with an accompanying decrease in plasma volume of 3.4 percent was observed in the sixteen high school wrestlers studied. After a one-hour rehydration period, body weight was still 2.6 percent below initial body weight, indicating the wrestlers would be entering competition in a state of dehydration. Nevertheless, heart rate and stroke volume were restored to normal levels and the authors concluded that PWC was significantly restored.

Acute and Chronic Semi-Starvation

Under conditions of restricted food intake a caloric deficit will result in using energy reserves in the body in the form of fat, carbohydrate, and protein. A decrease in the capacity to perform physical work is directly associated with a long-term reduction in available fuel. The Minnesota Experiment (35) was conducted to determine the effects of long term semi-starvation and rehabilitation in man. The semi-starvation period lasted 24 weeks and involved 34 men of varying fitness levels. The controlled diet was designed to bring about a 24 percent weight reduction during the course of the investigation. The actual average weight loss was 24.2 percent. Most of the weight loss occurred in the first few weeks although a steady decline took place throughout the study. The average body fat lost amounted to 83.3 percent of the estimated initial values. Basal metabolism was observed to decrease by 19.5 percent. Submaximal aerobic work capacity as determined by a treadmill decreased by 28.3 percent. Anaerobic work capacity measured with a treadmill version of the Harvard Step Test resulted in a severe decline; 71.6 percent. Associated decreases in maximal oxygen consumption, respiratory efficiency, a reduced oxygen debt and lactate concentration were found after running to exhaustion. A reduction in strength, as measured by a standard hand and back dynamometer decreased by 25.6 and 26.2 percent, respectively. It was concluded that long-term semi-starvation results in significant impairment for the variables measured.

In studying the effects of acute and semi-starvation on PWC, Henschel and co-workers (27) performed two experiments. Four men were placed on a 2½-day fast (acute starvation), and twelve men were placed on a five-day fast (semi-starvation). The subjects in the 2½-day fast recorded an average total caloric deficit of 9,000 Kcal and a decrease in total body weight by 6.7 percent. The subjects in the five-day fast had an average total caloric deficit of 10,000 Kcal and a decrease in total body weight by 7.8 percent. The subjects walked on a treadmill at a 10 percent grade and at 3.5 m.p.h. pace for four hours each day in the 2½-day fast and for three hours per day in the five-day fast. No changes were observed in performance until the morning of the second day, at which time work pulse rates increased by 10-15 beats/min. Blood glucose levels decreased during work by 25 mg/100 ml, and anaerobic capacity as measured by the Harvard Step Test decreased 30 percent by the second day and another 30 percent by the fourth day.

In a similar study, Taylor and co-workers (55) studied the effects of dietary controls on PWC under conditions of semi-starvation. The experimental group was divided into two subgroups. One group had 13 subjects and consumed 1010 Kcal/day for 24 days, and the second group had six subjects and consumed 580 Kcal/day for 12 days. The experimental subjects consumed daily diets of pure carbohydrate and ingested 4.5 mg of NaCl and a multivitamin preparation. A control group of six men consumed a mixed diet consisting of 3100 Kcal/day. The weight losses of the subjects were not provided. Work was performed by walking on a treadmill at a 10 percent grade and 3.5 m.p.h. for one hour and a 1½-hour walk outside each day. Anaerobic capacity was determined from the Harvard Step Test. Results indicated that: (a) blood glucose levels during work were not maintained on the 580 Kcal/day diet; (b) both experimental diets prevented the occurrence of the debilitating effects of ketosis, which are often associated with acute starvation; (c) strength measurements were unchanged for weight losses less than 10 percent; and (d) maximal oxygen consumption declined slowly, but when expressed per kilogram of body weight, no significant decrease occurred until weight loss exceeded 10 percent. From the data collected it was concluded that when at least 580 Kcal/day and supplements are provided, ketosis, dehydration and hypoglycemia are prevented under conditions of moderate energy expenditure, and PWC is maintained for weight losses of up to 10 percent.

An investigation into the effects of successive fasts on PWC was performed by Taylor and co-workers (56). The protocol consisted of placing four men on five 2½-day fasts. Each fast was separated by five- to six-week intervals. Caloric expenditure on the first day was approximately 4,500 Kcal, 4,000 Kcal on the second, and 2,000 Kcal on the third day. Weight lost during each fast was not provided. Work was carried out on a treadmill at a 10 percent grade and at a 3.5 m.p.h. pace. "Anaerobic" work was performed by running for 1¼ minutes at 9 m.p.h. at a 10 percent grade. Psychomotor tests were also carried out. From the results it was concluded that: (a) the subjects were able to maintain blood glucose levels during work at a significantly higher level in the fifth as compared to the first fast; and (b) motor speed and coordination were less impaired during the fifth than the first fast. Reaction time and pattern tracing were also improved in the fifth as compared to the first fast. It was generally concluded that repeated exposure to the fasting state results in an improved adaptation to fasting.

Summary

In summarizing this review of related literature, it may be concluded that:

1. High-ability wrestlers are characterized by low levels of body fat, with "optimal" levels of approximately six to nine percent.

2. The recommended minimum level of body fat is five percent.

3. Rapid weight reduction is practiced by the majority of amateur wrestlers and is primarily brought about through semi-starvation, exercise, and/or dehydration. This regimen may be repeated numerous times during the course of a competitive season.

4. Following a weight loss of greater than three or four percent of total body weight brought about by dehydration, muscular endurance will remain unchanged but physical working capacity may be impaired.

5. When a recovery period of five hours with unrestricted fluid intake is permitted following weight losses of up to seven percent of total body weight as a result of dehydration, physical working capacity will return to normal levels even though a complete replacement of body fluids does not occur.

6. A gradual weight reduction greater than approximately ten percent of total body weight through semi-starvation will significantly impair physical working capacity.

7. Subjects repeatedly exposed to fasting are observed to make an improved adaptation to subsequent fasting.

CHAPTER III

PROCEDURE

Research Method

This research was conducted to determine the relationship between nutritional control and selected physical parameters on twenty-five male college wrestlers. A "randomly" selected experimental group (EG) was placed on an individualized high carbohydrate-hypocaloric diet. A control group (CG) received no dietary direction to aid in reducing body weight.

Subjects

The EG was composed of the wrestlers who resided in the MSU dormitories. Dormitory cafeterias serve standardized food items which permitted accurate individualized menu planning and recording. The CG consisted of the wrestlers living off-campus (Table 3).

Table 3. Mean Age, Height, Weight, and Body Composition for the Pre-Test on 18 Collegiate Wrestlers.

Variable	EG	CG
Age (years)	18.6	20.0
Height (inches)	66.9	68.3
Weight (pounds)	149.4	165.9
Body Density	1.079	1.083
Lean Body Weight (pounds)	135.6	152.8
Percent Body Fat	9.2	7.6

Revised Population

Twenty-five male college wrestlers composed the original population. The EG was composed of eleven subjects, and the CG was made up of fourteen subjects. Of the original twenty-five subjects, only eighteen completed the testing for various reasons. In the EG, one subject sustained an injury preventing further testing; two subjects dropped out of the wrestling program; and one subject withdrew himself from further testing. In the CG, one subject sustained an injury and two subjects dropped out of the wrestling program.

Dietary Program

A. Experimental Group

1. A nutritional program based upon the foods available in the MSU dormitory cafeterias was individually designed for each subject:

a) based on their estimated basal metabolism as determined from body surface using the DuBois Nomogram (22), and

b) from an estimation of Kcal expended performing daily activities (Appendix A).

2. The degree to which each diet was calorically restricted was based on the relationship of how much weight each subject was required to lose in order to reach their weight classification and the time available for such a weight loss to occur. Several factors determine the weight classification in which the subjects compete: the subjects' total body weight and percent body fat, the number and quality of

teammates vying for the same varsity position, and conferences with the coach. The final decision is made by each wrestler.

3. The composition of all diets, regardless of the number of calories included, was composed of a minimum of 60 percent carbohydrates and contained a minimum of one gm of protein per kilogram of body weight.

4. Vitamin supplementation, protein powders, etc., were not permitted during the investigation for either group.

5. Subjects were counseled on how to measure standard portions of food items and how to keep records of foods not listed on their menu plan. Daily menu plans were posted in the MSU dormitory cafeterias each morning for each subject. The food items and amounts to be selectively consumed were listed. If, for any reason, a change in the daily menu occurred (i.e., substitutions, additions and/or omissions), they were recorded on the menu plan or daily recall list.

B. Control Group

1. The CG was required to reduce their body weight in order to reach their weight classification with no directions on the type or quantity of foods to be consumed.

2. Sample records of food intake were collected during alternating weeks of the investigation (Oct. 3-10; Oct. 24-31; and Nov. 7-14, 1983).

3. Each subject was counseled on how to perform routine record keeping of their food intake (i.e., portion size, ingredients). They were required to turn in each day a list of their previous day's meals (including all snacks). If, for any reason, a dietary record was not

turned in, then a memory recall for the missing time period was performed by a trained investigator.

Testing Battery

The testing parameters were as follows:

1. Body Composition
    a. Chest skinfold (CH)
    b. Subscapular skinfold (SU)
    c. Tricep skinfold (TR)
    d. Suprailiac skinfold (SI)
    e. Abdominal skinfold (AB)
    f. Thigh skinfold (AB)
    g. Percent body fat (PF)
    h. Lean body weight (LBW)
    i. Fat weight (FW)
2. Girths
    a. Neck (NE)
    b. Chest (CH)
    c. Shoulders (SH)
    d. Bicep (BI)
    e. Forearm (FA)
    f. Wrist (WR)
    g. Abdominal 1 (AB 1)
    h. Abdominal 2 (AB 2)
    i. Gluteal (GL)
    j. Thigh (TH)

k. Knee (KN)

l. Calf (CA)

m. Ankle (AN)

3. Height (HT)

4. Total Body Weight (TBW)

5. Muscular Endurance

a. Squat

b. Dips

c. Pulldowns

d. Seated overhead press

6. Power

a. Modified-Wingate Test

7. Aerobic Endurance

a. 1½-mile run

8. Urine Analysis

a. Specific gravity

Testing Equipment and Procedures

Body Composition. Skinfold measurements were taken with Lange Skinfold Calipers. Standardized procedures were used as described by Keys (36), and Behnke and Wilmore (8). Three measurements to the nearest 0.5 mm were taken, with an average of the three used as the score. If one measurement deviated by more than 1.0 mm, the measurements were repeated. All measurements were performed on the right side of the body, and were located with the use of a plastic tape measure and marked to ensure accuracy and consistency. The sites of the skinfolds were as follows:

1. Chest (CH) - Halfway between the nipple and the armfold.

2. Subscapular (SU) - At the tip (inferior angle) of the right scapula, on a 45-degree line laterally downward.

3. Tricep (TR) - Vertical fold on the posterior line halfway between the tip of the acromion process and the olecranon process, arm hanging at side.

4. Suprailiac (SI) - Vertical fold on the right mid-axillary line just above the crest of the ilium.

5. Abdominal (AB) - Horizontal fold adjacent to the right of the umbilicus.

6. Thigh (TH) - Vertical fold on the anterior right thigh in the midline, halfway between the patella and the greater trochanter.

Density was computed from the skinfolds using an average of the following formulas:

$D_B = 1.1043 - .001327\ (TH) - .00131\ (SU)$ (Sloan)

$D_B = 1.1017 - .000282\ (AB) - .000736\ (CH) - .000883$ (Sharkey)

$D_B = 1.1080 - .00168\ (SU) - .00127\ (AB)$ (Forsyth-Sinning)

Density was converted to percent body fat using an average of the following formulas:

$\frac{4.57}{D_B} - 4.142 \times 100 = \text{Percent Fat (PF)}$ (Brozek)

$\frac{4.95}{D_B} - 4.500 \times 100 = \text{Percent Fat (PF)}$ (Siri)

<u>Girths</u>. Measurements of girth were taken using the procedures of Behnke and Wilmore (8) at the following sites:

1. Neck (NK) - Just inferior to the larynx.

2. Chest (CH) - Nipple line at mid-tidal volume in males.

3. Shoulders (SH) - Laterally, at the maximal protrusion of the deltoid muscles, and anteriorly, at the articular prominence of the sternum and second rib.

4. Bicep (BI) - Maximal girth of the mid-arm when flexed to the greatest angle with the underlying muscles fully contracted.

5. Forearm (FA) - Maximal girth with the elbow extended and the hand supinated.

6. Wrist (WR) - Minimal girth just distal to the styloid processes of the radius and ulna.

7. Abdominal 1 (AB 1) - Laterally, midway between the lowest lateral portion of the rib cage and the iliac crest, and anteriorly, midway between the xyphoid process of the sternum and the umbilicus. This level is the natural waist and is readily identified as the level of minimal abdominal width when the side profiles are slightly concaved.

8. Abdominal 2 (AB 2) - Laterally, at the level of the iliac crests, and anteriorly, at the umbilicus.

9. Gluteal (GL) - Anteriorly, at the level of the symphysis pubis, and posteriorly, at the maximal protrusion of the gluteal muscles.

10. Thigh (TH) - Just below the gluteal fold or maximal thigh girth.

11. Knee (KN) - Mid-patellar level, slightly flexed, weight transferred to opposite leg.

12. Calf (CA) - Maximal girth.

13. Ankle (AN) - Minimal girth, superior to the malleoli.

Height. The height of the individual was taken while standing with his back placed firmly against a wall, and with his chin parallel to the floor. Height was recorded from calibrated markings placed on the wall. Measurements were recorded to the nearest ¼-inch. A metal square was placed on top of the head and against the wall alongside the markings.

Weight. The weight of the individual was determined using a certified Toledo spring scale. Measurements were recorded to the nearest ½-pound.

Muscular Endurance. A measurement of muscular endurance was made by determining the number of repetitions which could be performed for a given percent of the subject's body weight. The subjects warmed up with ten minutes of stretching exercises. Verbal encouragement was given. The sequence of the tests remained uniform during testing periods, but rest periods were not standardized. All of the tests were routinely used in training by all subjects. The tests and procedures were as follows:

1. Squats - The lifter must take the bar off the rack in a horizontal position, hands gripping the bar, feet flat on the platform. He must wait for the signal to "squat." After the signal the lifter will bend the knees and lower the body until the top surfaces of the legs at the hip joint are equal to or below the tops of the knees. The lifter may recover at will, without double bouncing, to an upright position. The amount of weight to be lifted will be 150 percent of the subject's body weight for as many repetitions as possible.

2. Dips - The subject will start the lift in a fully extended arm position and when ready will lower the body until the top surface of the

shoulder is lower than the top of the elbow. The lifter may recover at will to a fully extended position, with elbows locked. The amount of weight to be lifted will be equal to body weight with an additional twenty percent of the subject's body weight added via a dipping belt.

3. "Lat" pulldowns - Utilizing a "Lat" Machine, the lifter will begin from a fully extended position. The bar must be pulled down to the top of the trapezius muscles at the base of the neck, after which the bar will again be returned to a fully extended arm position. The lifter's thighs must remain under the restraining bar throughout the test. The amount of weight to be utilized will be equal to the lifter's body weight for as many repetitions as possible.

4. Seated overhead press - The lifter will be seated on a bench and the bar will be placed behind the neck. The lifter will raise the bar from his shoulders to a fully extended position (elbows locked) and then lower it to a position behind the neck at the level of the trapezius muscles at the base of the neck. The amount of weight to be utilized will be equal to sixty percent of the lifter's body weight for as many repetitions as possible.

Power. A modification of the Wingate Test (31) was utilized as a measure of anaerobic metabolism. The test was modified by a one-minute reduction for both the warm-up and rest periods. The order in which the subjects performed the test was maintained between the Pre- and Post-Test. The subject warmed up on a bicycle ergometer for four minutes at 2 kp, with a sprint of four- to seven-seconds duration at one-minute intervals (1:00, 2:00, and 3:00). The warm-up was followed by a three-minute rest period. The test began at 2 kp, and the resistance was increased to a predetermined workload based on the subject's body weight in three to four seconds. The subject then performed an all out effort for thirty seconds without any pacing. The number of revolutions for each five-second period of the work test was recorded with the use of a Pacer 2000H (Sportronics) rpm meter. From this data, maximal anaerobic power, anaerobic capacity, and resistance to fatigue were determined.

Aerobic Endurance. Aerobic endurance was measured using a 1½-mile run. Testing was performed on an indoor 200-meter track in the MSU Fieldhouse. The test was done separately in two groups. Verbal encouragement was given, as well as the lap time and number. A ten-minute warm-up was given before testing began.

Urine Analysis. Urine samples were collected to provide information on the extent of dehydration in addition to body weight and subsequent rehydration in preparation for competition. Specific gravity was measured by an Adams Midget Urinometer Float. Samples were taken in the morning before the subjects had urinated, consumed food, ingested water, or exercised within an eight-hour period prior to weigh-in. All samples were collected between the hours of 7-8 a.m. A second urine sample was taken between 12-1 p.m., just prior to competition.

Testing Schedule

A pre- and post-test battery was given during the six-week study. Anthropometric testing was performed before the study began so that dietary programs for each of the subjects in the EG could be determined. The week prior to muscular endurance testing was used as a trial period to familiarize the subjects with testing procedures and to minimize the learning effect. Mid-point in the investigation (Oct. 24), skinfold testing was again performed in an effort to evaluate the progress of the EG dietary program, as well as the CG.

The testing schedule is given below:

Sept. 21-22	Anthropometric Testing (4:30)	Pre-Test
Sept. 30	1½-Mile Run (3:30)	
Oct. 4	Muscular Endurance Testing (4:00)	
Oct. 5	Modified-Wingate Test (3:00)	
Oct. 24	Anthropometric Testing (3:30)	
Nov. 10	1½-Mile Run (3:30)	Post-Test
Nov. 11	Muscular Endurance Testing (4:00)	
Nov. 14	Anthropometric Testing (3:30)	
Nov. 15	Modified-Wingate Test (3:00)	
Nov. 17-18	Urine Analysis (8:00 a.m. and 12:00 noon)	

<u>Analysis of Data</u>

An analysis of covariance between the EG and the CG for each variable tested was performed, using the pre-test as the covariate. The level of significance was established at 0.05. The tables, figures and statistics are expressed as means for all the variables measured in this investigation.