Effects of standard set weight training and circuit weight training on excess post exercise oxygen consumption
by Emmett Thomas Murphy

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 study was to compare the effects of standard set weight training and circuit weight training on excess postexercise oxygen consumption. The exercises and order of exercises were the same for both programs. The weight programs differed in three respects: 1. a circuit approach as opposed to three sets of the same exercise; 2. the percent of maximum weight used was high in standard weight training (80%) and low in circuit weight training (50%); and 3. the rest periods were shorter for circuit weight training (30 seconds) than standard weight training (120 seconds). This longer rest period resulted in a longer standard program (50 minutes) than the circuit program (19 minutes) . Ten untrained, college males performed both weight training programs. Resting metabolic rate was determined prior to each weight program followed by a determination of excess postexercise oxygen consumption.

The magnitude and duration of excess postexercise oxygen consumption produced by circuit weight training were significantly (P<.01) greater than those produced by standard weight training. The excess postexercise oxygen consumption produced by circuit weight training was 2 0 minutes in duration with a net caloric cost estimated at 24.9 kilocalories while that produced by standard weight training was 15 minutes in duration with an estimated net caloric cost of 13.5 kilocalories. The intensity of circuit weight training (638 pounds per minute) was also . greater than that of standard weight training (233 pounds per minute).

The weight training programs used in this study did not produce a prolonged excess postexercise oxygen consumption. However, the intensity of the weight training program affected both the magnitude and duration of excess postexercise oxygen consumption. The magnitude and duration of excess post exercise oxygen consumption produced by weight training was similar to that found for aerobic exercise. The magnitude of excess post exercise oxygen consumption produced by weight training was found to be a substantial portion of the total energy cost. Therefore, excess post exercise oxygen consumption may be of some significance in weight control.

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This thesis has been read by each member of the graduate 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.

Aug. 8, 1990 — Robert J. Schwarzkopf

Date — Chairperson, Graduate Committee

Approved for the Major Department

8/13/90

Date — Head, Major Department

Approved for the College of Graduate Studies

August 15, 1990 — Henry L. Parsons

Date — Graduate Dean

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ABSTRACT

The purpose of this study was to compare the effects of standard set weight training and circuit weight training on excess postexercise oxygen consumption. The exercises and order of exercises were the same for both programs. The weight programs differed in three respects: 1. a circuit approach as opposed to three sets of the same exercise; 2. the percent of maximum weight used was high in standard weight training (80%) and low in circuit weight training (50%); and 3. the rest periods were shorter for circuit weight training (30 seconds) than standard weight training (120 seconds). This longer rest period resulted in a longer standard program (50 minutes) than the circuit program (19 minutes). Ten untrained, college males performed both weight training programs. Resting metabolic rate was determined prior to each weight program followed by a determination of excess postexercise oxygen consumption.

The magnitude and duration of excess postexercise oxygen consumption produced by circuit weight training were significantly (P<.01) greater than those produced by standard weight training. The excess postexercise oxygen consumption produced by circuit weight training was 20 minutes in duration with a net caloric cost estimated at 24.9 kilocalories while that produced by standard weight training was 15 minutes in duration with an estimated net caloric cost of 13.5 kilocalories. The intensity of circuit weight training (638 pounds per minute) was also greater than that of standard weight training (233 pounds per minute).

The weight training programs used in this study did not produce a prolonged excess postexercise oxygen consumption. However, the intensity of the weight training program affected both the magnitude and duration of excess postexercise oxygen consumption. The magnitude and duration of excess post exercise oxygen consumption produced by weight training was similar to that found for aerobic exercise. The magnitude of excess post exercise oxygen consumption produced by weight training was found to be a substantial portion of the total energy cost. Therefore, excess post exercise oxygen consumption may be of some significance in weight control.

CHAPTER 1

INTRODUCTION

Excess postexercise oxygen consumption (EPOC) is the additional energy expenditure following exercise due to a metabolic rate elevated above the resting level (Gaesser and Brooks, 1984). Any physical exertion will cause an increase in EPOC upon completion of exercise (Sedlock, Fissinger, and Melby, 1989). Estimates of the duration of EPOC range from 10 minutes to 48 hours (Bahr, Ingnes, Vaage, Sejersted, and Newsholme, 1987; Freedman-Akabus, Colt, Kissileff, and Pi-Sunyer, 1985; Kaminsky, Kanter, Lesmes, and Laham-Saeger, 1987; Knuttgen, 1970; Maehlum, Grandmontagne, Newsholme, and Sejersted, 1986; Pacy, Barton, Webster, and Garrow, 1985; and Sedlock et al., 1989). The primary reason for the large range is due to the influence of different intensities and durations of exercise.

The cellular basis of EPOC has not been clearly established. Gaesser and Brooks (1984) concluded that an explanation of EPOC is directly related to the mitochondrion. They contend that EPOC may be influenced by a number of factors including: lactate levels, creatine phosphate concentrations, catecholamine levels, lipolysis, ion concentrations, and core and tissue temperature. However, the degree of influence of these factors and their relation to different types of exercise has not been expressly determined.

Some researchers have linked EPOC with the potential for weight control (Sedlock et al., 1989; and Maehlum et al., 1986). The caloric cost of EPOC is not included in energy expenditure estimates, therefore, a knowledge of the added caloric cost related to the type, intensity, and duration of exercise can be beneficially employed by overweight individuals.

Researchers who have studied EPOC have either used cycling, walking, or jogging as the mode of exercise. Many people use weight training as a recreational and fitness activity. Questions about the EPOC of weight training, and its magnitude in comparison to that found for aerobic exercise need to be answered.

Statement of the Problem

The purpose of this study was to examine and compare the effects of standard set weight training and circuit weight training on excess postexercise oxygen consumption.

Hypotheses

1. Circuit weight training and standard set weight training will not yield statistically different EPOC's.

2. The EPOC from weight training will be similar to that from aerobic exercise.

Definitions

1. Repetition: Performing a lift through the full range of motion (Kraemer and Fleck, 1988).

2. Set: Performing a lift for a specified number of repetitions (Kraemer and Fleck, 1988).

3. Absolute muscular strength: The maximum amount of weight which can be properly lifted for 1 repetition (1-RM) (Berger, 1982).

Operational Definitions

1. Standard set weight training (SWT): A series of exercises in which multiple sets of one exercise are completed before moving to another exercise.

2. Circuit weight training (CWT): A series of exercises in which one set is performed before moving to the next exercise.

Delimitations

This study was delimited to ten novice volunteer college males.

Limitations

1. Selection of subjects was based on sex, age, available time, and previous weight lifting experience.

2. Subjects were not randomly selected from a larger

population group.

3. The exercises used are a small sample of many weight training exercises.

4. Factors involved in the mechanism of EPOC, such as lactic acid levels, core temperature, hormone levels, etc., were not measured.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The primary focus of this study was to compare the effects of two different weight training programs on EPOC. EPOC serves as a repayment of the "oxygen debt" acquired during exercise. EPOC is the process by which the body returns to resting homeostasis. Several studies investigating the influence of aerobic exercise on EPOC have been completed. However, many questions remain regarding the duration of EPOC, the cellular basis of EPOC, the effects of EPOC on fit and unfit individuals, and the comparative effect of weight training to aerobic exercise on EPOC. This chapter will provide a review of the current research related to EPOC structured in the following manner:

1. Basis of EPOC
2. Duration of EPOC
3. Effects of EPOC in Fit and Unfit Individuals

Basis of EPOC

The specific cellular mechanism(s) responsible for EPOC have not been identified. Gaesser and Brooks (1984) stated that any explanation of EPOC will be associated with the mitochondrion, the site of cellular respiration. These same authors listed the direct factors which control the mitochondrion: ADP (adenosine triphosphate), ATP (adenosine diphosphate), Pi (inorganic phosphate), and CP (creatine phosphate). Indirect factors which they considered to be of importance are: catecholamines, thyroxine, glucocorticoids, fatty acids, calcium ions, and temperature. The contribution of these indirect factors remains uncertain (Sedlock et al., 1989).

Indirect factors may influence EPOC at different times. Margaria, Edwards, and Dill (1933) termed a faster first phase as alactacid oxygen debt, and a slower second phase as lactacid oxygen debt. These terms were based upon the belief that lactic acid played the primary role in EPOC. The majority of researchers now believe that lactic acid does not play as large a role as was once thought. The terms used today are rapid-recovery O2 phase (RRP) and slow-recovery O2 phase (SRP) (Fox, Bowers, and Foss, 1989). Fox et al. (1989) defined the RRP as the first phase which lasts about 2-3 minutes characterized by a rapid decline in oxygen consumption and the SRP as the second phase which is characterized by a slower decline in oxygen consumption to resting levels.

Creatine Phosphate and Adenosine Triphosphate

Muscular contractions use energy from the breakdown of ATP to ADP and Pi. CP is used to reform ATP from ADP and Pi. ATP and CP are rapidly restored following exercise (Fox et al., 1989). Gaesser and Brooks (1984) stated that the changes in CP concentrations may be responsible for most of the RRP and part of the SRP. Oxygen can be utilized during aerobic metabolism to oxidize carbohydrates and fats to generate the energy needed to rebuild ATP (Fox et al., 1989; and Kraemer and Fleck, 1982). The half life of ADP and Pi is approximately 20 seconds and in 3-5 minutes all of the ATP that was broken down will be restored (Kraemer and Fleck, 1982). Gaesser and Brooks (1984) estimated that the portion of EPOC needed for ADP and creatine rephosphorylation will not exceed 1.5 l of oxygen or 10% of the total EPOC volume following exercise.

Elevated Temperature (Q10 effect)

Temperature may be the most important factor contributing to EPOC (Gaesser and Brooks, 1984). Increased temperature in muscle and other tissues is a direct result of exercise. The Q10 effect expresses the increase in the rate of chemical action, therefore, the rate of O2 consumption by the mitochondrion (Brooks and Fahey, 1984; and Gaesser and Brooks,1984). Hagberg, Mullin, and Nagle (1980) estimated that the Q10 effect could account for 60-70% of the SRP of EPOC during work loads of any intensity and duration.

Calcium Ions

Calcium ions have been associated with an increase in oxygen consumption by the mitochondrion (Carafoli and Lehninger, 1971). Muscle cell contraction is triggered by calcium ion release from the sarcoplasmic recticulum. The calcium ions are transported via an active transport system, which requires energy in the form of ATP, to the muscle cell. Brooks and Fahey (1984) stated that this increase in energy is reflected in an increase in oxygen consumption for the increased energy needs required by active transport and the increased concentration of calcium ions in the mitochondria may be related to the increased regeneration of ATP which requires added oxygen consumption (Brooks and Fahey, 1984).

Hormones

Elevated levels of catecholamines and other hormones elevated during and after exercise can also cause an increase in EPOC (Barnard and Foss, 1969; Cain and Chapler, 1981; and Gladden, Stainsby, and MacIntosh, 1982). Epinephrine, thyroxine, and glucocorticoids cause an increase in Na-K pump activity which results in increased energy utilization (Gaesser and Brooks, 1984). Brooks and Fahey (1984) concluded that "because exercise affects both Na and K balance, and hormone levels, these factors probably serve to elevate oxygen consumption after exercise" (p. 201).

Fatty Acids

Gaesser and Brooks (1984) theorized that fatty acids may increase EPOC. Their explanation was that the mobilization of fatty acids during exercise may increase the need for their oxidation in mitochondria.

Lactic Acid

Hill and associates originally theorized that oxygen used in the SRP phase of EPOC was utilized for the oxidation of lactate and its conversion back to glycogen (cited in Gaesser and Brooks, 1984). Gaesser and Brooks (1984) stated that while lactic acid is often associated with anaerobic metabolism, lactate levels are influenced by factors other than oxygen deficiency. They have demonstrated that all types of exercise will result in lactate production.

The majority of lactic acid is oxidized following exercise (Gaesser and Brooks, 1984). However, Brooks and Fahey (1984) stated that this does not cause an increase in EPOC because lactate is a metabolic fuel. The authors reasoned that the oxygen used by the conversion of lactate to pyruvate would be used by the conversion of glucose to pyruvate if lactate was not present. Therefore, lactate does not cause an significant increase in EPOC. Roth, Stanley, and Brooks (1988) studied the effects of circulatory occlusion on blood lactate levels and EPOC. They found that, although blood lactate levels were significantly increased (380%), EPOC was not significantly elevated in the SRP.

In summary, the cellular basis of EPOC is clearly linked with the mitochondrion. Numerous factors could have an influence on mitochondrial respiration. However, the degree of influence of these factors remains uncertain.

Duration of EPOC

Researchers who have studied the duration of EPOC have often found conflicting results. Sedlock et al. (1989) studied the effects of (1) different intensities of exercise with equal caloric expenditures, and (2) equal intensities of exercise but different durations, on EPOC. Ten male triathletes volunteered to perform three exercise programs on a cycle ergometer: (1) 75% of VO2 max for approximately 20 minutes (high intensity- short duration, HS), (2) 50% of VO2 max for approximately 30 minutes (low intensity-short duration, LS), and (3) 50% of VO2 max for approximately 60 minutes (low intensity-long duration, LL). The subjects were instructed to fast for 12 hours and refrain from strenuous exercise for a minimum of 36 hours. Resting VO2 was measured over a period of 60 minutes while the subjects were seated. The authors found a similar duration of EPOC for the HS program (33 min) and LL program (28 min). The duration of the LS group (20 min) was significantly lower than the other two groups.

Hagberg, Mullin, and Nagle (1980) also studied the effects of exercise intensity and duration on EPOC. Eighteen male subjects completed six exercise programs on a cycle ergometer at 50, 65, and 80% of their VO2 max for 5 and 20 minutes. They did not use a resting VO2 as the baseline. Their baseline VO2 was determined by having the subjects ride at 150 rpm for five minutes. The authors found durations of EPOC which ranged from approximately 10 to 35 minutes.

Bahr et al. (1987) studied the effect of different durations of exercise on EPOC. Six male subjects exercised on a cycle ergometer at 70% of VO2 max for 80, 40, and 20 minutes. The subjects were instructed not to eat after dinner on the night prior to testing. They were also instructed not to participate in any exercise two days prior to testing and to refrain from alcohol and tobacco for 24 hours prior to testing. Resting VO2 and EPOC were determined while the subjects lay in bed. Metabolic rate was determined over a 24 hour period and the subjects were fed three meals during this time. The first meal was given two hours after exercise. Bahr et al. found the duration of EPOC to be at least 12 hours, and not more than 24 hours following all exercise durations.

Kaminsky et al. (1987) used 24 male subjects to study EPOC following aerobic exercise of different intensity and duration that required equal energy expenditure. Resting VO2 was determined after the subjects sat quietly for 20 minutes. The subjects either exercised by walking at 35% of VO2 max for 60 minutes or by running at 70% of VO2 max for 30 minutes. The authors found the duration of EPOC to be no longer than 20 minutes for both groups.

Maehlum et al. (1986) studied the duration of EPOC in four female and four male subjects. Subjects were instructed to report to the lab after an overnight fast and to refrain from exercise for two days prior to testing. Resting VO2 was determined during the last 15 minutes of a 30 minute rest period. The subjects were required to work at 70% of VO2 max for approximately 80 minutes on a cycle ergometer followed by bed rest for 24 hours. The subjects were fed three meals during this rest period. Meals were given at any time following exercise dependent on the preference of the subjects. The authors found that EPOC lasted at least 12 hours.

In summary, the duration of EPOC has been estimated to range from 10 minutes to 48 hours. However, the majority of research has not found EPOC to be prolonged. Researchers that have not found a prolonged EPOC fasted their subjects following exercise, while researchers finding a prolonged EPOC have not.

Effects of EPOC in Fit and Unfit Individuals

The effect of training on the intensity and duration of EPOC has also produced conflicting results. Freedman-Akabas et al. (1985) studied the effect of different fitness levels of subjects on EPOC. Ten men and 13 women were placed into one of three groups based upon their fitness levels. The subjects were instructed to refrain from food four hours prior to the test. Resting VO2 was measured after a 30 minute rest period. EPOC was measured while subjects worked on a treadmill at their anaerobic threshold for 20 minutes or 40 minutes. The researchers found the duration of EPOC to be no more than 40 minutes for any group at any duration. There were no significant differences in EPOC between the different fitness groups.

Brehm and Gutin (1986) studied the effects of intensity, exercise type, and fitness level on EPOC. They used a group of eight joggers and eight sedentary adults who walked and/or ran at different intensities. Each group was composed of an equal number of males and females. There were no restrictions placed on diet or activity level. Resting VO2 was determined using three minute measurements until the difference between two consecutive measurements was less than 5%. The duration of VO2 ranged from 18-48 minutes for both groups at all intensities. No significant difference was found between joggers and sedentary adults with respect to the duration of EPOC when exercising at equal intensities.

Girandola and Katch (1973) studied the effects of endurance training on EPOC. A control group of 33 male college students was compared with an experimental group, also consisting of 33 college males, who participated in a nine week training program. Both groups were pre- and post-tested at the same workloads. The researchers found that after training there was a decrease of .31 liters of oxygen for 15 minutes of recovery.

Hagberg, Hickson, Ehsani, and Holloszy (1980) also studied the effects of endurance training on EPOC. Eight male subjects were placed on an aerobic training program which increased their VO2 max by 24%. Subjects were pre- and post-tested at 50% and 70% of their VO2 max on a cycle ergometer to determine the effects of this training program on EPOC. The researchers found that the magnitude of EPOC was lower at the same absolute work load and was not significantly different at the same relative work load. The period required for oxygen consumption to return 90% of the way to the resting value ranged from 56-74 minutes. The researchers also found that the duration of EPOC was significantly less after training at both the same absolute and relative workloads.

In summary, the effect of training on EPOC is uncertain. Freedman-Akabas et al. (1985) and Brehm and Gutin (1986) found that training produced no effect on the duration of EPOC. Hagberg, Hickson, Ehsani, and Holloszy (1980) and Girandola and Katch (1973) found that both the duration and intensity of EPOC were affected by training. The researchers who found no training effect used a cross-sectional design with trained and untrained subjects, while the researchers who found a training effect used a longitudinal design pre- and post-testing the same subjects.

Conclusions

There are many unanswered questions regarding the cellular basis of EPOC, the duration of EPOC, and the effect of training on EPOC. Many factors have been associated with EPOC on a cellular level. While the degree of influence of these factors remains uncertain, the chemical action of these factors is definitely associated with the mitochondrion. The duration of EPOC has been estimated to vary from 10 minutes to several days. This discrepancy is most likely associated with the different protocols employed by researchers. Researchers who have fed subjects following exercise have found prolonged EPOC's. The effect food has on increasing oxygen consumption may explain a prolonged EPOC (Sedlock et al., 1989). The effect of training on the magnitude and duration of EPOC is also a contentious subject which directly relates to the protocol employed by researchers. Researchers who have found that training reduces the magnitude and duration of EPOC have used longitudinal type studies. Researchers who have not found a training effect on EPOC have generally used cross-sectional designs.

CHAPTER 3

METHODOLOGY

Subjects

Ten volunteer college males, ranging in age from 18-31 participated in the study. None of the subjects had used weight training as a consistent form of exercise in the past year. Informed consent was obtained from all subjects before testing began.

Table 1. Physical Characteristics of the Subjects.

Characteristics	Statistic	
	Mean	Standard Deviation
Age (years)	23.6	3.9
Height (inches)	70.6	1.95
Weight (pounds)	177.2	23.5

Study Design

Subjects performed both the circuit weight training (CWT) and the standard weight training program (SWT) in a balanced randomized crossover design with one week between tests.

Dependent Variables

Pre-exercise VO2

Subjects arrived at the laboratory where all testing was performed at approximately 3:00 P.M. on each test day. Subjects were instructed not to eat after 12:00 noon, and to refrain from caffeine, tobacco, and alcohol after 10:00 A.M. Subjects were also instructed to refrain from any vigorous physical activity on the day of testing. All subjects were familiarized with procedures before testing began.

Subjects were seated in a relaxed position for approximately 10 minutes before their baseline VO2 was measured. A five minute measurement was taken to determine their resting VO2. Ventilatory measurements were made by open circuit spirometry. A Modified Otis-McKerrow valve conducted air into a Collins Chain Compensated Tissot. Ventilatory samples were passed through a paramagnetic oxygen (Beckman E-2) analyzer and an infrared carbon dioxide (Beckman LB-2) analyzer. Both analyzers were calibrated prior to each test with gases of known concentration. Standardized methods of oxygen consumption determinations were used (Howley and Franks, 1986).

Post-exercise VO2

Subjects were seated immediately following exercise. One minute VO2 measurements were taken during the first minute of six consecutive five minute intervals.

Independent Variables

Strength and Endurance Testing

Subjects were tested for absolute muscular strength, 1-RM (repetition maximum), on five exercises: power clean, bench press, squat, biceps curl, and seated military press using standardized procedures (Berger and Hardage, 1967; and Westcott, 1983). These 1-RM tests were used to determine relative resistance for the CWT and SWT tests. Bent knee situps were tested on a flat situp bench with the hands crossed on the chest. Each subject completed as many situps as possible until exhaustion. This muscular endurance test was used to determine the number of situps performed during the SWT program. Muscular strength and endurance testing was completed over two days at least one week prior to the first scheduled program.

Circuit Weight Training

Free weights were utilized for all exercises except situps. The program consisted of six exercises in the following order: power clean, bench press, squat, biceps curl, seated military press, and bent knee situps. The sequence of exercises was designed to allow at least 45 seconds rest between exercise bouts for similar muscle groups. The weight used was approximately 50% of 1-RM for each exercise. The subjects performed three circuits with 30 seconds rest between exercises. Each exercise consisted of 12 repetitions for the first set, 10 for the second and 8 for the final set. Subjects did as many situps as possible in 30 seconds for each set. The average time required to complete the CWT program was 19 minutes with a standard deviation of 0.8 minutes.

Standard Weight Training

The SWT program used the same six exercises in the same order as the CWT program. Rest periods were 2 minutes between sets and exercises. Three sets of one exercise were performed before moving to the next exercise. The resistance for all three sets was 80% of 1-RM. As many repetitions as possible were performed for each set.

A warm up set was used for the power clean, squat, and bench press with a 90 second rest before the first work set. Each warmup set consisted of doing approximately 6 repetitions at 60% of 1-RM. Bent knee situps were done with a ten pound weight held across the chest. Subjects who had completed more than fifty situps during their endurance test performed three sets of 15 repetitions. Subjects who had completed less than fifty situps performed three sets of 10 repetitions. The average time required to complete the SWT program was 50 minutes with a standard deviation of 1.1 minutes.

Statistical Design

Group means were computed for all dependent variables. Dependent t tests were used for comparisons within groups and between groups at a level of significance of .01.

CHAPTER 4

RESULTS

The findings of this study are presented in this chapter under the following headings:

1. Excess Post Exercise Oxygen Consumption of the CWT and SWT Programs.
2. Respiratory Exchange Ratios.
3. CWT and SWT Work Load and Intensity Comparisons.

Excess Post Exercise Oxygen Consumption of the CWT and SWT Programs

The methods used were designed to measure differences in EPOC of the two different weight lifting programs for ten college males. The results are summarized in Table 2 and Figure 1. Individual results for both the CWT and SWT programs are given in Table 2.

Figure 1 provides the results of a statistical analysis within the CWT and SWT programs and between the two programs. The results from this statistical analysis (P<.01) indicate: 1) that there was no significant difference between the two resting VO2 measurements (RMR); 2) the CWT program produced a significant EPOC for approximately 20 minutes and the SWT program showed a significant EPOC for approximately 15

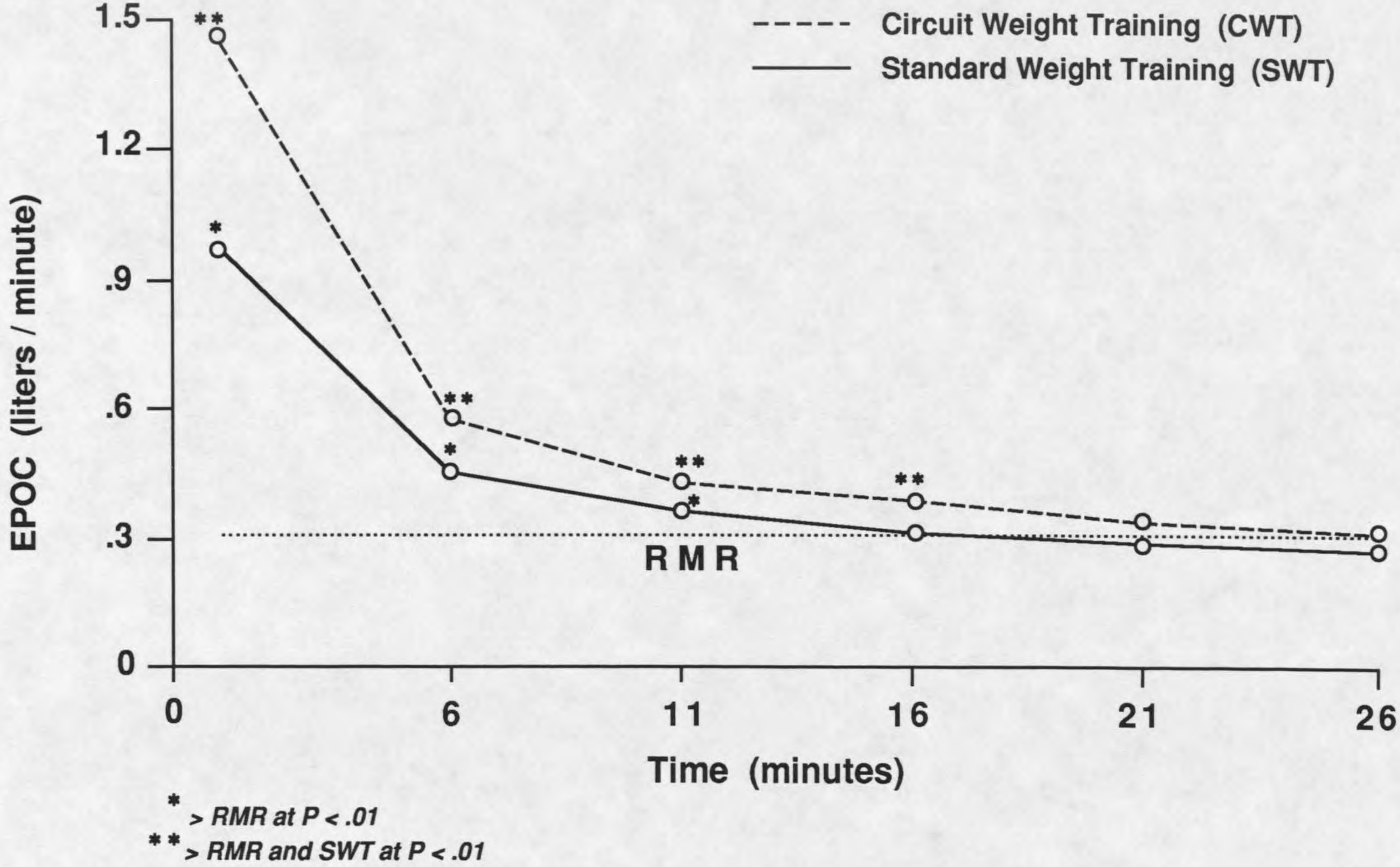

Figure 1. Excess Postexercise Oxygen Consumption (EPOC) of Circuit Weight Training (CWT) and Standard Weight Training (SWT).

minutes; and 3) the EPOC produced by the CWT program was significantly elevated above that produced by the SWT program for approximately 20 minutes.

Table 2. Individual and Group Results of the CWT and SWT Programs Related to EPOC (liters/min).

		Sampling Minutes Postexercise					
Subject	Rest	1	6	11	16	21	26
			CWT				
1	.33	1.66	.65	.44	.41	.36	.33
2	.31	1.55	.51	.40	.37	.29	.33
3	.33	1.52	.58	.50	.42	.43	.40
4	.28	1.32	.57	.40	.40	.41	.35
5	.34	1.62	.48	.35	.38	.30	.32
6	.26	1.57	.60	.49	.37	.35	.25
7	.26	1.67	.59	.40	.33	.26	.26
8	.33	1.25	.57	.42	.40	.31	.29
9	.39	1.53	.73	.56	.51	.48	.40
10	.33	.88	.51	.41	.33	.25	.21
mean	.31	1.45	.58	.43	.39	.34	.31
			SWT				
1	.34	1.00	.51	.44	.43	.42	.35
2	.29	.87	.44	.40	.36	.25	.30
3	.29	.95	.43	.32	.32	.33	.32
4	.26	.83	.45	.39	.31	.33	.32
5	.33	1.01	.46	.35	.26	.28	.26
6	.25	1.12	.43	.35	.27	.26	.23
7	.23	1.30	.42	.29	.23	.21	.23
8	.34	.80	.45	.37	.37	.31	.29
9	.36	1.02	.50	.34	.30	.31	.27
10	.29	.80	.41	.38	.24	.20	.14
mean	.30	.97	.45	.36	.31	.29	.27

Respiratory Exchange Ratios

The respiratory exchange ratios (RER) of the CWT and SWT programs are shown in Table 3. The CWT program caused an elevation in the RER immediately after exercise, followed by a return to resting levels. The SWT program caused a decrease in the RER directly after exercise followed by a increase and a decrease to below resting levels.

Table 3. Mean Values of the Respiratory Exchange Ratios.

Time(mins)	CWT	SWT
Rest	.962	.942
Recovery		
1	1.059	.939
6	1.051	.962
11	.982	.934
16	.919	.888
21	.879	.853
26	.833	.848

CWT and SWT Work Load Comparisons

The average total weight lifted (work) during the CWT program, not including situps, was 12,122 pounds which equals 808 pounds per set. A corresponding average of work completed during the SWT program, also not including situps, was 11,628 pounds which equals 775 pounds per set. The average length of the CWT program was 19 minutes, resulting in an intensity (work/time) of 638 pounds per minute and, similarly, an average of 50 minutes and intensity of 233 pounds per minute for SWT (Tables 4 and 5).