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# A Simulation of a Multi-Hop Communications Network Using a Kinematic Topology Generator and Static Sphere-Packing Power Control

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# THE EFFECTS OF AEROBIC CONDITIONING UPON THE RESTING METABOLIC RATE

by

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THE EFFECTS OF AEROBIC CONDITIONING
UPON THE RESTING METABOLIC RATE

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This study compared the metabolic rate following an exercise bout to the resting metabolic rate (RMR) established in pretesting procedures for twelve college age females. The only factor differentiating the groups was length of the training period (one week, two weeks, four weeks, and five weeks). Training took place on a Bosch cycle ergometer three times a week, for 30 minutes each session, at 70 to 85 percent of the subjects' heart rate reserve (HRR). Breath analysis was measured on a Beckman Metabolic Cart in both pretesting and post-testing procedures.

The findings indicated that aerobic exercise, performed at 70 to 85 percent of the HRR for 30 minutes, elevated the individual's RMR for at least 90 minutes following the exercise. No statistically significant difference was observed in the acute elevation of the RMR between the four groups; however, significant differences in the RMR occurred between subjects, regardless of group affiliation. Variables including workload, exercising heart rate, percentage of HRR utilized during the exercise sessions, and body fat were analyzed to determine their contribution to the elevated RMR levels. No statistical significance was found; however, it appeared that higher intensities and larger workloads increased the magnitude of the excess post-exercise oxygen consumption.

It was concluded that aerobic exercise would prove beneficial for weight reduction programs; not only for the energy expended during the activity, but also for the extra energy utilized during the recovery period.

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# The effects of aerobic conditioning upon the resting metabolic rate

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# CHAPTER I

## INTRODUCTION

Weight loss and/or weight management are extremely important objectives for many in American society. Numerous aspects associated with the attainment of these goals have been researched from the early 1900s. Many people have turned to fad diets and exercise programs in their quest for the "ideal weight." People spend substantial amounts of money on weight management programs, although in the majority of cases, failure is the end result.

One factor that cannot be overlooked when attempting to manipulate body weight is resting metabolic rate (RMR). Resting metabolism is measured in ml/kg/min and represents the oxygen intake of the body. Resting metabolism and basal metabolism are often used synonymously. However, Karpovich in 1941 reported that resting metabolism represented the amount of energy expended during inactivity, while basal metabolism was the lowest level of energy necessary for mere existence. Owen (1988) stated that one's basal metabolic rate occurs only transiently during early morning hours of deep sleep. Resting metabolic rate occurs while a subject is resting and fasting. Freedman-Akabas, Colt, Kissileff, and Pi-Sunyer (1985) stated that daily changes in eating patterns, stress, and activity make measurement of RMR along with interpretation of the results extremely difficult. Many things influence an individual's RMR; diet can either increase or decrease RMR, exercise has been thought to increase RMR, alcohol consumption, the menstrual cycle, sleep patterns, and nicotine have been shown to influence RMR.

Many studies dealing with the RMR have investigated its influence on an individual's ability, or in most cases, inability to lose weight. Studies indicated that caloric restriction generally results in a depressed RMR, which reduces the amount of weight loss that occurs. Kardong (1989) reported that RMR has been shown to decrease up to 15 percent within a few days of dieting. Dieting usually results in a decrease in fat-free mass which leads to a reduction in body weight. This outcome is misleading to the dieting individual. Granted, the absolute body weight is less, however, the amount of active tissue in the body is also less. Therefore, RMR remains depressed and fewer calories are needed to sustain the individual in daily activities. Therefore, most people who participate in a restrictive diet end up regaining weight.

Exercise has also been utilized for the manipulation of one's weight. While it does appear to result in improved health and physical fitness, it may not be the best method. Exercise does help to maintain lean body mass (LBM) which can preserve, and possibly increase the RMR; however, unless the diet is monitored as well, exercise only helps to regulate the present weight.

When both methods are used simultaneously, preferential results are often experienced. Hagan, Upton, Wong, and Whittam (1986) studied overweight men and women while they consumed a diet of 1200 kcal per day and/or exercised for five days a week. Results indicated that body weight and fat weight decreased significantly more with diet and exercise versus one method or the other. In addition to weight loss and an elevated RMR, individuals approaching weight management in this manner tend to form healthy life long habits, which result in extended weight control.

Although the combination of dieting and exercising appears to be an optimal approach, there is still a great deal of contention encompassing the topic. Major controversy surrounding this issue concerns the magnitude and duration of the elevation in oxygen consumption following exercise. This excess in oxygen consumption that follows exercise has recently been termed excess post-exercise oxygen consumption (EPOC). In the past, investigators believed that , the RMR remained elevated for approximately 24 hours after the cessation of exercise. If EPOC occurs, a great deal of energy would be utilized in the recovery stage associated with exercise. This would have major ramifications for weight loss and weight maintenance programs. However, more recent research has supported the idea that the benefits gained from exercise take place during the activity and the early recovery phase. Less than one hour has been proposed as the recovery phase in which EPOC occurs. If this is the case, exercise may play a less significant part in obtaining an optimal weight than originally thought.

## Statement of the Problem

This investigation was conducted to determine the effect that aerobic conditioning, performed for 30 minutes at an intensity of 70 to 85 percent of the heart rate reserve, has on the resting metabolic rate.

## Purpose of the Study

The purpose of this study was to determine whether 30 minutes of exercise at an intensity level of 70 to 85 percent, of maximal heart rate reserve, was sufficient to elevate the subject's post-exercise RMR for a time period of 90 minutes. This would not prove the actual time length of EPOC, unless it was less than this period, but it would establish a time period greater than what is currently believed to occur.

## Significance of the Study

Due to the substantial number of individuals in our society that are weight conscious, the need to understand one of the most important concepts associated with weight management is increasing. Resting metabolic rate is thought to contribute approximately 65 to 75 percent of an individual's daily energy expenditure. This statistic is true regardless of how high or low a person's RMR actually is. It appears that elevating an individual's RMR, through a healthy method, could only have a positive impact on any weight management program. Researchers, in the past, have made the claim that exercise is the healthy method to do the job.

More recent research has failed to find that physical exertion produces a substantial increase in RMR. The increase that does result, researchers often attribute to some other factor. Informing the public of the most accurate, up-to-date observations on RMR, is the primary objective of the exercise science populace.

Regardless of the findings of this particular study, exercise will always be rewarding to those who participate in it as a way of life. Elliot and Goldberg (1985) believed that exercise positively affects fat oxidation, attitude, self-esteem, and increases feelings of vigor throughout an individual's day, all of which are important attributes that cannot be ignored.

## Delimitations

This study was delimited to the following:

1. Participants were college age females.

2. All subjects were students at Western Michigan University, Kalamazoo, and were volunteers interested in starting an exercise program.

3. The two dependent variables monitored during the exercise bouts were heart rate and workload. Oxygen consumption was monitored in the pre- and post-test periods only.

4. The intensity range selected for the exercise bouts was from 70 to 85 percent of the subject's heart rate reserve.

5. The exercise sessions took place three times each week, Monday, Wednesday, and Friday for 30 minutes each day.

6. Pretesting took place on four consecutive days, Wednesday, Thursday, Friday, and Saturday for one hour at the same time on all four days.

7. Post-testing took place on four consecutive days, Wednesday, Thursday, Friday, and Saturday for two hours at the same time on all four days.

## Limitations

The limitation of this study was that the subjects were selected randomly, from respondents to announcements made in physical education classes. For this reason, most of the subjects were younger and at least slightly active. Results, therefore, may not apply to other populations.

## Assumptions

It was assumed that participants would take part in all of the scheduled workouts and testing sessions at the appropriate time each week. It was also believed that the individuals would abstain from consuming alcohol during the testing days. Although diet was not restricted, the subjects were encouraged to ingest meals of similar quantity and quality during the testing periods.

## Hypothesis of Study

The experimental hypothesis of this study was as follows. It was believed that performing 30 minutes of an aerobic activity, at a workload of 70 to 85 percent of the heart rate reserve, would result in a prolonged elevation of RMR following exercise.

## Definition of Terms

The terms that were specific to this study included:

1. Absolute resting metabolic rate - refers to the actual value of energy expended regardless of an individual's weight or fat-free mass.

2. Acute effect - the immediate response of the metabolic rate to the exercise stimulus.

3. Aerobic metabolism - metabolism which utilizes oxygen.

4. Anaerobic metabolism - metabolism that occurs in the absence of oxygen.

5. Basal metabolic rate (BMR) - defined as the amount of energy expended simply to support existence (Karpovich, 1941).

6. Chronic effect - the long term elevation in the RMR following a consistent training regimen.

7. Excess post-exercise oxygen consumption (EPOC) - the amount of oxygen used by the body, above the RMR, following exercise that was in response to the exercise.

8. Exercise-induced thermogenesis - the metabolic state associated with augmented energy expenditure; heightened metabolic state accompanying exercise.

9. Heart rate reserve - variation between the maximal heart rate and the resting heart rate.

10. Karvonen's formula - a technique used to calculate the target heart rate range.

11. Maximal heart rate (MHR) - the upper limit that an individual's heart can beat in a minute and still maintain optimal efficiency; derived by the following formula: MHR = 220 - age.

12. Postprandial period - also called dietary-induced thermogenesis. The metabolic state associated with augmented energy expenditure; heightened metabolic state accompanying ingestion of food (Owen, 1988).

13. Relative resting metabolic rate - refers to the value of energy expended per unit of fat-free mass.

14. Resting metabolic rate (RMR) - defined as the amount of energy expended during resting and fasting (Owen, 1988).

15. Target heart rate range - a span that is acceptable for the heart rate to be within during exercise bouts.

## CHAPTER II

## REVIEW OF LITERATURE

The resting metabolic rate has been the subject of many investigations in the past and probably will continue to be studied until the current uncertainties surrounding it are cleared up and the findings are regarded as facts. The majority of the recent studies involving the RMR have discussed its affects upon a person's disposition towards obesity. The current society is regarded as overweight, therefore, it is important that investigators determine the causes of this disorder. Researchers are attempting to determine whether individuals who suffer from obesity are different in respect to RMR values when compared to leaner individuals. Owen (1988) reported that RMR was the best predictor of overall requirements for ambulatory adults. The RMR contributed 65 to 75 percent of the daily energy expended. Dolgener and Larsen (1984) stated that in obese subjects, the RMR accounted for an even larger majority of the daily energy expended.

Other studies were conducted to determine the effects that other variables may have on the RMR. The primary issues with this research have been diet and exercise. Other variables like stress, menstrual cycle, sleep patterns, and smoking have been mentioned as confounding variables, however, the fundamental topics have been diet and exercise.

### Contributing Variables

Owen (1988) explained that the largest portion of the RMR is held constant throughout life due to the tissues that contribute to the greatest part of the RMR.

According to Owen, the brain, which only constitutes approximately two percent of the body's total weight is responsible for 20 percent of the RMR. The liver contributes another 20 percent to the RMR, while contributing about two percent to the total body weight. The muscle tissue accounts for 35 to 40 percent of the body's total weight, while providing 20 percent to the RMR value. Adipose tissue is responsible for anywhere from 5 to 50 percent of the body's total weight, however, contributing 2 to 5 percent to the total RMR. Since the majority of the fluctuations in body weight that occur throughout life are additions of lower-energy requiring tissues, the RMR deviates only slightly in response to gradual weight gain or loss.

When weight loss is more rapid due to severe caloric restriction, the RMR tends to decrease in order to preserve the fuel sources that are already present in the body. Elliot, Goldberg, Kuehl, and Bennett (1989) placed seven obese subjects on a severely restricted diet (300 kcal/day). Results revealed that the RMR of these subjects decreased by 22 percent during this phase. A maintenance diet of 1100-1400 kcal/day was administered following the initial dieting. Elliot et al. measured the RMR of the seven subjects eight weeks after the end of the initial dieting period. At that time, the RMR was still significantly depressed even with the adherence to the extra calories.

Hensen, Poole, Donahoe, and Heber (1987) placed seven moderately obese women on a diet for nine weeks. The caloric intake per day for this period was 800 kcal. During weeks four through six, an exercise program was implemented. The subjects biked for 30 minutes, five days a week, at an intensity level of 70 percent of the maximal heart rate reserve. In the first three weeks, the RMR decreased by 13 percent. The exercise period proved beneficial in improving the $VO_2$ max, but did not elevate the dietary depressed RMR. The greatest decrease in body fat was observed in weeks four through six, which resulted in a small increase in the absolute RMR; however, the relative RMR remained unchanged.

Bogardus et al. (1986) reported that the majority of the variance in the RMR (83 percent) was accounted for by three covariates; fat-free mass, age, and gender. Of these three, fat-free mass is presumed to be the most important determinant. Elliot et al. (1989) stated that fat-free mass actually accounted for 80 percent of the variability in RMR. In 1988, Owen reported that the most highly correlated variables with RMR included: weight, body surface area, lean body mass, body cell mass, and fat-free mass measured by densitometry. Owen concluded that weight was the most easily and accurately measured variable, therefore, if estimations are made, weight would be an appropriate variable to use. Owen also found that the predicted values of RMR that are used today overestimate the true values found by indirect calorimetry.

Gender has been considered to be an important contributor to RMR. Bogardus et al. (1986) reported that gender is only an important determinant when considering absolute values of RMR. This finding indicated that RMR was less likely to be a function of gender and more likely a function of fat-free mass. Women tend to possess smaller proportions of fat-free mass than do males, therefore, women's absolute RMR values are significantly less than those found in men. If relative values are observed, then the differences observed between the genders are negated.

Bogardus et al. (1986) found that family history plays an important role in determining the RMR values of individuals. An additional 11 percent of the variance of RMR is explained when family membership is considered. Bogardus et al. stated that individual inconsistencies in energy intake and energy expenditures probably contribute to positive energy balance and obesity in humans.

*Studies Concerning the Obese*

Ravussin, Burnand, Schutz, and Jequier (1982) compared the RMR and energy expenditure of obese, moderate obese, and control subjects. The results indicated that both the RMR and the energy expenditure absolute values were higher in the obese;

however, the relative values for the same parameters were similar for all groups. Elliot et al. (1989) supported these findings and reported that RMR of obese individuals, when normalized for the amount of fat-free body weight possessed, were comparable to those of nonobese individuals. Ravussin et al. (1982) also found that the expended energy was higher for obese individuals. This was attributed to the higher RMR along with the higher energy cost associated with simply moving and performing daily activities.

Segal and Gutin (1983) performed an interesting study that observed both lean and obese subjects' response to exercise and/or eating. In the first trial, the subjects exercised at a 300 kpm/min workload followed by a meal or simply rest. In the second treatment, the subjects cycled at individual anaerobic thresholds and then either consumed a meal or rested. Finally, the subjects either rested and then ate or continued to rest. The results indicated that the thermic effect of food was similar for both groups after the final period in which only rest was incorporated. Segal and Gutin discovered that exercise enhanced the thermic effect of food following exercise, but only for leaner subjects. These researchers believed that the reduced response to the combined stimulus of food plus exercise, may have contributed a subtle metabolic factor associated with obesity.

## Physical Activity

Physical activity has been assumed to increase an individual's RMR by a variety of methods. Elliot and Goldberg (1985) reported that physical activity has the potential to affect three important aspects of a weight loss regimen: appetite, energy expenditure, and body composition. Firstly, exercise has been associated with an increase in appetite thus initiating the consumption of more calories. Elliot and Goldberg believed that the activity may enhance the thermic effect of meals aiding in the oxidation of fat. The main issue is to control the type of extra calories that are consumed. If nutrient dense calories are absorbed and the thermic effect of the food is increased, then heightened appetite would not prove to be an obstacle for the weight conscious individual. Secondly, people who participate in daily exercise programs tend to exhibit higher energy levels throughout the day. Elliot and Goldberg pointed out the fact that lean subjects perform more rigorous activities in daily living than do obese individuals. This might be a result of the added effort that is necessary for an obese individual to perform the more vigorous activity, or it might simply be that an exercising person has more energy to take part in more energy requiring activities. Finally, exercise helps an individual maintain lean body mass (LBM) as they move through the aging cycle. It is widely accepted that as an individual ages, LBM is reduced significantly unless steps are taken to preserve it. By maintaining the body's LBM, a person conserves some of the tissue that contributes to the RMR, therefore, the RMR is preserved to some degree as well, which can prove beneficial in warding off unwanted weight.

No disagreement exists concerning the increase in the metabolic rate (MR) during the exercise period. All of the studies, reviewed for the current research, have stated this fact. An understanding also exists that a recovery period follows the cessation of the exercise.

## Recovery Phase

The magnitude and the duration of the recovery phase is the point at which a controversy originates. Various researchers have described the activity that takes place during this period. Initially, Karpovich (1941) stated that with strenuous exercise, a person depends on two types of energy: aerobic, which utilizes oxygen, and anaerobic, which takes place in the absence of oxygen. As a result of the anaerobic process, Karpovich explained that a person will be in a state of dyspnea at the end of the work period. Following the termination of exercise, the individual will continue to use excess oxygen until recovery is complete. This approach was one of the earliest hypotheses and was a simplistic explanation of what takes place; however, the stage was set for future research to investigate this topic. More recent investigations described the recovery phase in a short and concise manner. The more exercise disturbs the body's resting homeostasis, the greater the effect on the recovery metabolism (Brehm & Gutin, 1986). Felts, Crouse, and Brunetz (1988) added a slightly different viewpoint; the MR will return to normal when all the factors that influence mitochondrial respiration have returned to resting levels. Opportunity for the development of several different approaches was made possible by the definition of Felts et al.

Today researchers believe that the recovery period is divided into two, and sometimes three separate stages. The rapid component occurs immediately after the exercise is completed. Newsholme (1980), reported that this phase may be explained by the replenishment of creatine phosphate stores and the reoxygenation of the myoglobin and hemoglobin. This corresponds with what Karpovich (1941) revealed. The slow phase takes place after the initial decrease in metabolism and has been reported to last anywhere from 40 minutes to 48 hours. Bahr, Ingnes, Vaage, Sejersted, and Newsholme (1987) stated that exercise of 70 percent or more intensity is known to deplete the glycogen stores completely. Also replenishment of the glycogen stores took place at a much slower rate and may have required 48 hours to be fully restored. Newsholme (1980) reported that the slow component may be due to the reconversion of the byproduct lactate to glucose and glycogen, but that the amount of extra oxygen consumed in this phase is usually considerably larger than could be explained by carbohydrate synthesis. The excess, in Newsholme's opinion, may be due to the stimulation of the rates of the substrate cycles. Newsholme suggested that if cycles are stimulated for 100 minutes at a 20 percent higher rate than normal, 94 kJ of energy would be expended. More realistically, he proposed that if the cycles remained elevated for 24 hours with only a five percent increase, 340 kJ of energy would be utilized. If the latter is the case, a substantial gain would result not only from the exercise, but also from the recovery phase that follows exercise.

Newsholme was not the only researcher to attribute a portion of the slow phase to something other than carbohydrate synthesis. Brehm and Gutin (1986) also discussed the role that increased concentrations of catecholamines can play in sustaining the slow phase of recovery. Hagberg, Mullin, and Nagle (1980) recognized the fact that the catecholamines are increased, but they attributed little or no credibility to the fact that catecholamines may play a role in elevating the MR throughout the slow component. Hagberg et al. believed that the entire process can be explained by either lactate metabolism (30 percent) or increased body temperature (60-70 percent). On the other hand, Brehm and Gutin (1986) believed that only 28 percent of the variability observed in the recovery $VO_2$ could be explained by elevation in temperature.

Bielinski, Schutz, and Jequier (1985) supported the concept that carbohydrate metabolism, sympathetic activity stimulation, protein synthesis, and temperature elevation are responsible for the slow component of recovery. Bielinski et al. attributed approximately 10 percent of the EPOC to carbohydrate synthesis. Increased urinary catecholamines following exercise were also observed. However, Bielinski et al. described the extremely high cost of protein synthesis. According to these reviewers, the creation of one mol of peptide bond requires six ATP units, which is fairly costly to produce. Felts et al. (1988) believed that lipolysis and free fatty acid mobilization, which occur during exercise, are responsible for elevating the oxygen consumption. Felts et al. also attributed approximately 41 to 56 percent of the variance to elevation in core temperatures, depending on the duration of the activity. However, the research of Felts et al.reported that, EPOC and core temperature both declined for the first hour. When measurement of both variables was carried out until resting levels were reached, the EPOC remained elevated long after the core temperature, thus indicating that some other process was responsible for the elevated MR. Bahr et al. (1987) supported the idea that exercise of an insufficient intensity or duration to raise the plasma fatty acids and/or the catecholamine levels may not result in a marked increases in EPOC.

It is apparent from the variety of perspectives found in the literature that the justification of the slow component has yet to be determined. It is becoming more acceptable to consider lactate metabolism, elevated temperature, protein synthesis, increased catecholamines, and increased lypolisis and free fatty acid mobilization as all contributors to the slow component of recovery oxygen uptake that follows physical exertion.

## Related Variables

### Intensity and Duration

Two variables, intensity and duration, need to be discussed when trying to determine the magnitude and duration of the EPOC. The manipulation of these variables often makes comparison of the various studies on this topic difficult.

Elliot, Goldberg, and Kuehl (1988) had individuals exercise at 80 percent of their $VO_2$ max for 10 and 30 minutes on separate days. They found that the MR was elevated during the activity by 32 and 37 percent, respectively. Apparently, the duration had little effect on the magnitude of the increased MR. The MR returned to resting values in 30 minutes for both situations. Elliot et al. (1988) concluded that the energy expended during the recovery phase following aerobic training resulted in only a minimal contribution to the total energy used.

Elliot et al.'s (1988) study contradicted what Chad and Wenger (1988) discovered when manipulating the duration of the activity period. Chad and Wenger explained that the EPOC may add significantly to the total energy expended in association with an activity when the duration is longer than five minutes and the intensity is greater than 50 percent. According to Chad and Wenger, when the exercise was increased from 30 to 45 minutes, the net EPOC increased by 2.35 times. When the duration increased from 30 to 60 minutes, the net EPOC was 5.3 times larger. Along with the increased magnitude, Chad and Wenger observed an increase in the duration of the EPOC period. The recovery time was reported at 128 $\pm$ 8.8 min., 204 $\pm$ 31.7 min., and 455 $\pm$ 59.9 min. after 30, 45, and 60 minutes of exercise respectively.

Bahr et al. (1987) tested various exercise durations for their effect on the EPOC. The exercise durations were 20, 40, and 80 minutes. The results showed EPOC lasted for 12 hours following all three durations. The magnitude of the EPOC changed from 5.1 $\pm$ 1.2%, 6.8 $\pm$ 1.7%, and 14.4 $\pm$ 1.2%, for exercise durations 20, 40, and 80 minutes, respectively. Bahr et al. found that a linear relationship existed between the exercise duration and the $O_2$ consumption that took place during the exercise and that the difference between the three values was significant. A linear relationship existed for the magnitude of the recovery $O_2$ consumed and the exercise duration. Bahr et al. concluded that exercise of a high intensity, carried out for at least 20 minutes will result in a significantly increased EPOC value.

Hagberg et al. (1980) exercised subjects at 50, 65, and 80 percent of $VO_2$ max in order to determine the role that intensity plays on increasing the EPOC. Subjects performed the three work intensities at two separate durations, five and 20 minutes. Hagberg et al. reported that changes in EPOC were not significantly different for the two durations when carried out at the lower two levels of intensity, 50 and 65 percent of $VO_2$ max. However, when the exercise was performed at the 80 percent intensity level, a substantial increase in EPOC existed following the 20 minute session compared to the five minute session. The findings indicated that somewhere between

65 and 80 percent intensity, the slow component of recovery $O_2$ was sustained. The explanation Hagberg et al. gave for this outcome was the change in core temperature and the change in lactate accumulation. The temperature was elevated during the longer duration at all intensities. Also, core temperature was significantly higher for each successive increase in intensity. The blood lactate accumulated significantly only during the longer duration of the highest intensity. For these reasons, Hagberg et al. believed that the duration of the slow component of the recovery $O_2$ was independent of workload and exercise duration unless the exercise was of a high intensity (>65%) and of a duration longer than five minutes.

Fitness Level

The literature did not regard the fitness levels of the subjects tested as being an important variable in the magnitude and duration of the EPOC. Hagberg, Hickerson, Ehsani, and Holloszy (1980) believed that fitness level warranted some investigation. Hagberg et al. found that adaptations to endurance exercise training may have enabled an individual to adjust to the energy requirement of constant load submaximal work more rapidly, which would result in a smaller $O_2$ deficit. These researchers also believed that the rate of recovery was more rapid after training, which would result in a smaller $O_2$ debt. Hagberg et al. (1980) discovered that exercising at 70 percent of an individual's $VO_2$ max before training had taken place, resulted in a recovery phase that consisted of both a rapid and a slow component. Following the training regimen, a change in the recovery pattern following exercise at 70 percent $VO_2$ max occurred so that all of the decline in $VO_2$ was rapid with only a suggestion of a small slow component.

According to these findings, delimitations need to be provided concerning the fitness level of the individuals in question. It is also possible, that across a prolonged study, individuals may become fit. Therefore, alterations in the recovery $VO_2$ may need to be made in order for the results to be comparable to other studies.

## Reported Perceived Exertion

Reported perceived exertion (RPE) is a subjective feeling that the individual has about the effort they are exerting during activity. It generally is in accordance with the physiological responses that are taking place in the body. However, under some instances, the subject may perceive their effort as different than the physiological signs indicate. Felts et al. (1988) described this occurrence by saying that individuals often cannot differentiate between perceived exertion and perceived fatigue. Current data suggests that, for short-term exercise at moderate workloads, fitness does not mediate RPE despite the necessarily lower metabolic demands present in more fit individuals. At higher intensity levels, however, perceived exertion can play a vital role in limiting an individual's effort. Fitness level is an important contributor to the fatigue factor, therefore, at higher intensities, less fit individuals will feel as if they are working harder although their physiological signs do not support these feelings.

## Similar Studies

A variety of studies have been completed concerning the effect of exercise and EPOC. From this review, it is clear that numerous variables can influence the EPOC. This may explain why the studies do not always culminate with the same conclusion. Some studies support the belief that the EPOC contributes a significant effect upon the energy expended in association with an activity. Others tend to oppose this belief, and feel that the public is being misled to believe that exercise is beneficial above and beyond the actual training period. Examples of these two perspectives are presented below.

## Opposition Studies

Elliot et al. (1988) have already been cited as opponents of the extended EPOC hypothesis. They reported the shortest duration for the EPOC found in the literature. Elliot et al. exercised subjects at a fairly high intensity level, 80 percent. Therefore, lack of intensity does not explain why the study failed to find a significant elevation in the MR. However, the authors stated that no difference existed between the individuals who exercised and the control values, only 30 minutes following the exertion. Elliot et al. concluded that the majority of the caloric use with exercise was during the activity. In Elliot et al.'s opinion, people partaking in exercise for the sole purpose of losing weight should be aware that the only benefits received are during exercise.

Freedman-Akabas et al. (1985) failed to find a sustained increase in $VO_2$ following exercise. Subjects exercised at various levels of fitness for 20 minutes at the anaerobic threshold. The testing of $VO_2$ consumption continued for three hours following exercise. However, Freedman-Akabas et al. were, also, unable to detect any elevation in MR from the 40 minute time interval until the end of the three hour testing period. Seven of Freedman-Akabas's et al. subjects continued the study by exercising for an even longer duration at a higher intensity. Similar findings resulted. The conclusion revealed that no appreciable caloric loss beyond that generated by the exercise period itself and the early recovery phase was found in either fit or unfit individuals.

## Support Studies

deVries and Gray (1963) were among the first researchers to report that exercise could have a lasting effect on the MR following the cessation of the exercise. They tested two subjects following exercise at two hour intervals: two, four, six, and eight hours. The subjects were tested twice weekly for six weeks. One of the testing periods followed an exercise bout and the other followed a rest period.

Both subjects continued to exhibit an elevated MR for six hours after the exercise was terminated. Subject A was elevated even at the eight hour interval, but Subject B had returned to resting levels. The authors believed that the variation in the responses that occurred between the two subjects were due to weight and fitness level differences. Subject A was considered significantly overweight while Subject B was only a few pounds over his estimated ideal weight. Subject B proved to be in better physical condition prior to the beginning of the treatment period. These conclusions agreed with what Hagberg et al. (1980) observed with more fit individuals. Consequently, deVries and Gray (1963) believed that a prolonged increase in metabolism following exercise is a real phenomena.

Maehlum, Grandmontagne, Newsholme, and Sejersted (1986) studied eight healthy subjects while exercising for 80 to 90 minutes at an intensity level of 70 percent $VO_2$ max. Following the exercise, the subjects rested in a respiratory chamber for 24 hours. Oxygen uptake, heart rate, rectal temperature, and blood lactate were measured hourly for the first 11 to 12 hours and then again at the 24-hour interval. Oxygen uptake was greater at all the measured time intervals following the exercise than it was on the control day. Heart rate remained elevated above the control values for 12 hours following the exercise bout. The rectal temperature was only elevated above control values for 30 minutes following the exertion period.

Another benefit that Maehlum et al. (1986) observed was the enhancement of the thermic effect of food following the exercise. The $O_2$ consumption following the first meal, which was administered two hours after the exercise ended, was elevated above that of the control day's values. Maehlum et al. reported that the respiratory quotient was lower on the exercise day than it was on the control day. This indicated that a greater amount of fat oxidation was taking place on the exercise day versus the control day. Maehlum et al. concluded that exercise contributes a variety of benefits to the individual, long after the actual activity has ceased.

Lawson, Webster, Pacy, and Garrow (1987) exercised six lean sedentary women for 10 weeks. The dietary intake of the subjects was not restricted throughout the study. Following the 10 weeks, the RMR was significantly elevated compared with the RMR recorded at the starting levels. The authors were uncertain about the explanation for the results, but believed that the elevated RMR values were due to a prolonged thermogenic effect of the exercise, increased energy intake, or a combination of the two. No alterations were observed in body weight or the body composition. Therefore, exercise alone was not a sufficient treatment for mild obesity. Based upon the findings, Lawson et al. reported that no prolonged thermic effect of the exercise occurred until after at least four weeks of consistent exercise. However, they did find that after 10 weeks of consistent exercise, the RMR and the fitness level of the subjects were improved considerably.

Lawson et al. (1987) observed a slightly different effect that exercise has on the RMR. This study did not look at the acute effect of the exercise, but instead, the focal point of the study was the chronic effect of exercise. Not only have studies supported the fact that aerobic conditioning can influence the immediate levels of the RMR following the exercise, studies have also supported the idea that with a specific regimen, the RMR can be increased.

# CHAPTER III

## DESIGN AND METHODOLOGY

The purpose of this study was to determine the effect that aerobic conditioning, performed for 30 minutes at 70 to 85 percent of the heart rate reserve, has on an individual's resting metabolic rate. The chapter is organized into four areas: (1) subject selection, (2) measurements, (3) basic design, and (4) statistical analysis.

### Subject Selection

A total of 13 subjects were selected from respondents to announcements made in various physical education classes. Personal data on the subjects are presented in Table 1. The subjects were females aged 18 to 21 years, with varying levels of fitness. The majority of the subjects reported very little physical activity in daily routines.

The study was approved by the Human Subjects Review Board at Western Michigan University, Kalamazoo. Appendix A contains the approval form. The subjects were questioned, prior to starting any of the treatment procedures, concerning their health. According to each individual, no health risks were present that would present problems for any of the subjects performing the exercise prescription. Each subject signed and dated the consent form. Refer to Appendix B for a copy of the consent form. Subject 6 had only recently stopped smoking and was assessed as being in extremely poor aerobic condition. Subject 12 suffered from asthma; however, the condition was controllable with an inhalant. Subject 9 experienced a high heart rate, 95 bpm, while resting; therefore, close supervision was necessary during the exercise phase of the study.

Table 1

Initial Subject Profiles

| Subject | Age (yrs.) | Menstrual cycle (Date of onset) | % body fat | Activity level |
|---|---|---|---|---|
| S1 | 20 | 6-8th | 18.0 | moderate |
| S2 | 19 | 10-12th | 32.9 | low |
| S3* | 19 | 2-6th | 29.0 | low |
| S4 | 20 | 20-24th | 25.7 | moderate |
| S5 | 19 | 26th | 23.2 | moderate |
| S6 | 18 | 5-10th | 29.5 | low |
| S7 | 20 | 24th | 18.8 | moderate |
| S8 | 21 | 20th | 22.9 | low |
| S9 | 20 | 21st | 27.5 | moderate |
| S10 | 18 | 25th | 17.0 | moderate |
| S11 | 18 | 14-16th | 24.5 | moderate |
| S12 | 20 | 5th | 27.0 | moderate |
| S13 | 19 | 8-10th | 28.3 | moderate |

Note. Age is in years. Menstrual cycle dates and activity level were determined by questioning the subject.
* indicates that subject withdrew prior to post-testing.

## Measurements

### Body Composition

Body composition was measured via hydrostatic weighing. Vital capacity was measured on a Pony Spirometer Model No 16503. The resulting data was analyzed with a computer program, FAT. Table 1 contains the body fat values obtained for each subject.

Body composition was determined to help establish the four experimental groups. Refer to Appendix C for the experimental groups. Lean body mass has been shown to be among the top predictors of resting metabolic rate (Elliot et al., 1988). For this reason, this researcher felt that body composition was an important variable to measure.

### Resting metabolic rate

The resting metabolic rate (RMR) was measured while subjects were lying in a supine position on a hospital gurney. The RMR was measured on four consecutive days before the exercise treatment was administered. When resting metabolism was measured on pretest days, subjects were required to lie supine for 20 minutes prior to the first reading. Data collection continued from that point and readouts were obtained every two minutes for 30 minutes.

The post-test values were collected on four consecutive days following a 30-minute exercise bout. Some subjects were only able to complete three testing days due to conflicts in the time schedule or minor ailments that occurred throughout the study. Appendix D reports attendance. When resting metabolism was measured following the exercise treatments, readings were collected after the initial eight minutes and then every four minutes for a total duration of 90 minutes.

The high and low values, for each day in the pretest, were omitted and the remaining figures were totalled and averaged for each individual. This value would serve as the RMR baseline level and would be used for comparison to post-test values. In the post-test, the four measures obtained in each time frame were averaged and the mean RMR was compared to the baseline value. Refer to Appendix E for RMR values.

The Beckman Metabolic Measurement Cart (MMC) was used to observe each subject's resting metabolic rate. The Exercise Metabolic Program No. 554371A was used during the gas collection and analysis procedures. The MMC was calibrated following every third subject during the pretest phase of data collection and before each subject during the post-test procedures. A gas of a known oxygen and carbon dioxide content was used to calibrate the OM-11 oxygen analyzer and the LB-2 carbon dioxide analyzer, respectively. Bias flow and volume gain were also calibrated.

## Basic design

### Pre-treatment

Subjects were presented a demonstration concerning how the resting metabolic rate would be monitored throughout the study. All of the experimental procedures, risks, and benefits were explained to the subjects, and the subjects voluntarily signed an informed consent form. Refer to Appendix B. The study was approved by the Human Subjects Review Board at Western Michigan University, Kalamazoo, before any procedures were undertaken. Refer to Appendix A for the acceptance form. Subjects were also familiarized with the cycle ergometer and the surroundings in order to decrease any anxiety that might have affected the training or the testing procedures.

The subjects were divided into four groups (A, B, C, & D) based upon their body fat and the date of the onset of their menstrual cycle. Body fat was used when groups were created so that the average body fat of each group was similar. Each group consisted of three people, with one subject left over. (Refer to Appendix C for the experimental groups) The mean body fat for each group was 26.35 $\pm$ .25 percent. The groups were also arranged so that the subjects' menstrual cycles fell within the same week. This was done so that testing would not take place while the menstrual cycle of any subject was occurring.

Treatment

Following the division into groups, the treatment was initiated. Group A exercised one week, Group B exercised two weeks, Group C exercised four weeks, and Group D exercised five weeks.

The first week of the study was the same for every subject. No exercise was allowed during this period. The subjects were pretested for four consecutive days at approximately the same time each day. The pretest consisted of 20 minutes of quiet rest followed by 30 minutes of gas analysis which was carried out on the Beckman Metabolic Cart. Data was printed out every two minutes so that approximately 35 to 40 values were gathered on each subject. These values were averaged in order to determine the individual's baseline metabolic rate.

The second week represented the beginning of the training phase. This training phase was the same for each group except for the length. The subjects exercised on a Bosch bicycle ergometer for 30 minutes, three times a week at 70 to 85 percent of their maximum heart rate reserve. Target heart rate was predicted using Karvonen's formula. The heart rate was monitored by an electronic heart rate monitor and was recorded every six minutes during the exercise. The workload in watts was also recorded every six minutes during the exercise. Averages of the heart rate and workload were determined for each exercise day and the results are presented in

Appendix F. Following the exercise bout, the subjects were required to cool down until their heart rates fell below 120 beats per minute.

The final post-testing took place the week immediately following the end of the training phase. This time varied for each group depending on the length of the training phase. Testing was the same for all groups. The post-test was conducted on four consecutive days at approximately the same time, under the same conditions as the pretest. For this test, the subjects completed an exercise bout exactly like that discussed previously, however, immediately following the exercise, the subjects were once again placed on the metabolic cart. The duration of this test was 90 minutes. Again the gases were analyzed and readouts recorded every four minutes. Results were averaged for each time period and were compared to the baseline levels calculated earlier.

## Statistical Analysis

Raw data included: (a) body composition via hydrostatic weighing, (b) baseline RMR (established by averaging approximately 40 individual values), (c) workloads in watts and heart rate in beats per minute every six minutes during the exercise bouts, (d) final RMR values every four minutes for a total of 90 minutes immediately following the exercise, and (e) the percentages of the heart rate reserve that the subjects worked at during the four post-test days. The information was analyzed at Western Michigan University, Kalamazoo, using the BMDP Computer Program . An Analysis of Variance (ANOVA), Split Plot Factorial statistical design with fixed effects was used to determine the effects that the independent variables had on the dependent variables. Where the variance proved significant, Tukey's Honestly Significant Difference (HSD) test for multiple comparisons was employed to determine at what point the means became significantly different. A simple ANOVA, Repeated Measures design was also used to determine whether any significant differences occurred across the post-test days for the following dependent variables: (a) resting metabolic rate, (b) workload, (c) heart rate, and (d) percentage of heart rate reserve. All analyses were evaluated statistically at the $p < .05$ level.

Three different designs were used to analyze the data. The independent variables for the initial ANOVA included: (a) groups with four levels, one week, two weeks, four weeks, and five weeks; and (b) time. The independent variable time had 23 levels: the first signified the RMR baseline value, and the 22 successive numbers portrayed the RMR values following the exercise bout. The first reading was gathered at eight minutes after the exercise and then continued at four minute intervals. The dependent variable for this design was the RMR values.

The second design was carried out four times and was a simple ANOVA Repeated Measures design. The design consisted of one independent variable, treatment days with four levels. The dependent variables included: (a) resting metabolic rate, (b) workload, (c) heart rate, and (d) percentage of heart rate reserve.

The final design was repeated five times. Two independent variables were again involved; two groups with six levels, and time with 23 levels. In the first analysis, the subjects were divided into two groups according to the average percentage of heart rate reserve that the individuals exercised at during the four post-test days. For the second analysis, the groups consisted of the six subjects with the highest percent body fat and the six subjects with the lowest percent body fat. In the third analysis, the subjects were again divided into two groups based upon the average workload that was utilized during the four post-test days. In the fourth analysis, four groups were created based upon the average percentage of the heart rate reserve that was obtained by the subjects on the four post-test days. Finally, the fifth analysis was carried out with the subjects being divided into four groups based upon the subject's body composition. The dependent variable was always RMR and had 23 levels across time.

## CHAPTER IV

## RESULTS AND DISCUSSION

This chapter summarizes the results obtained in the present study and discusses the ramifications of the results on an individual desiring to manipulate his/her weight. The purpose of this study was to determine whether a significant increase in an individual's RMR resulted due to aerobic exercise, performed at 70 to 85 percent of the heart rate reserve for a duration of 30 minutes. Not only was the objective to confirm that an elevation in RMR did take place, but to also establish a minimal length of time that the elevation persisted. It was the intention to confirm or reject, with this research, the findings of studies that support the idea that the RMR remained elevated for a duration less than one hour.

Raw data included: (a) body composition via hydrostatic weighing, (b) baseline RMR (established by averaging approximately 40 individual values), (c) workloads in watts and heart rate in beats per minute every six minutes during the exercise bouts, (d) final RMR values every four minutes for a total of 90 minutes immediately following the exercise, and (e) the percentages of the heart rate reserve that the subjects worked at during the four post-test days. The information was analyzed at Western Michigan University, Kalamazoo, using the Computer Program BMDP. An Analysis of Variance (ANOVA), Split Plot Factorial statistical design with fixed effects was used to determine the effects that the independent variables had on the dependent variables. Where the variance proved significant, Tukey's Honestly Significant Difference (HSD) test for multiple comparisons was employed to determine at what point the means became significantly different. The independent variables for the initial ANOVA included: (a) groups with four levels, one week, two weeks, four weeks, and five weeks; and (b) time with 23 levels. The first of the 23 levels reflected the RMR baseline value, and the other 22 successive readings portrayed the RMR values following the exercise bout. The first reading was gathered at eight minutes after the exercise and then continued at four minute intervals. A simple ANOVA, Repeated Measures design was used to determine whether any significant differences occurred between any of the subjects across the post-test days. These ANOVAS were run to ascertain which of the following dependent variables--resting metabolic rate, workload, heart rate, and percentage of heart rate reserve--were responsible for the difference. Finally, five more ANOVAS, Split Plot Factorial statistical design with fixed effects were utilized. All designs had two independent variables. The first independent variable was the group with varying levels, and the second was the time measured exactly like that previously described. The only difference between the designs was the characteristics used for the grouping procedures.

## Results

### Mean RMR Across the Experimental Groups

The descriptive data for the dependent variable, RMR for each group across the 23 time frames are presented in Appendix G. An ANOVA (see Table 2) was calculated using group and time as the independent variables. The RMR values at each time interval for each group member served as the dependent variable. The following results were identified from the ANOVA:

1. No significant difference in mean RMR values, $F = 1.11$, was found between groups ($F(3, 8) = 4.07$, $p < .05$).

2. A significant difference in the mean RMR values, $F = 15.71$, was observed between the time intervals ($F(22, 176) = 1.66, p < .05$).

3. No difference in mean RMR values, $F = .82$, was found for the first order interaction of time X group ($F(66, 176) = 1.43, p < .05$).

Table 2

ANOVA Summary Table for RMR Across the Experimental Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 121209.38 | 3 | 40403.13 | 1.11 |
| Error | 291629.18 | 8 | 36453.65 | |
| Within Subjects | | | | |
| Time (T) | 102478.66 | 22 | 4658.12 | 15.71* |
| T X G | 16040.37 | 66 | 243.04 | 0.82 |
| Error | 52193.99 | 176 | 296.56 | |

*$F(22, 176) = 1.66, p < .05$

For the comparison of the RMR values across the time intervals, Tukey's HSD test for multiple comparisons was used to locate significant differences between the time intervals within the subjects. Refer to Appendix H. The results of the analysis of mean differences of RMR values for time indicated that:

1. The baseline RMR value was significantly different from the mean RMR values across all time intervals ($q(8, 23) = 24.51, p < .05$).

2. The time interval corresponding to the eight minute RMR value was significantly different from all other time intervals.

Figure 1 illustrates that a significant decrease in the RMR occurs rapidly within the first two time intervals. From that point on, the decline takes on a more gradual pace. However, as evidenced in Figure 1, the values never descended completely to the resting values within the context of this study.

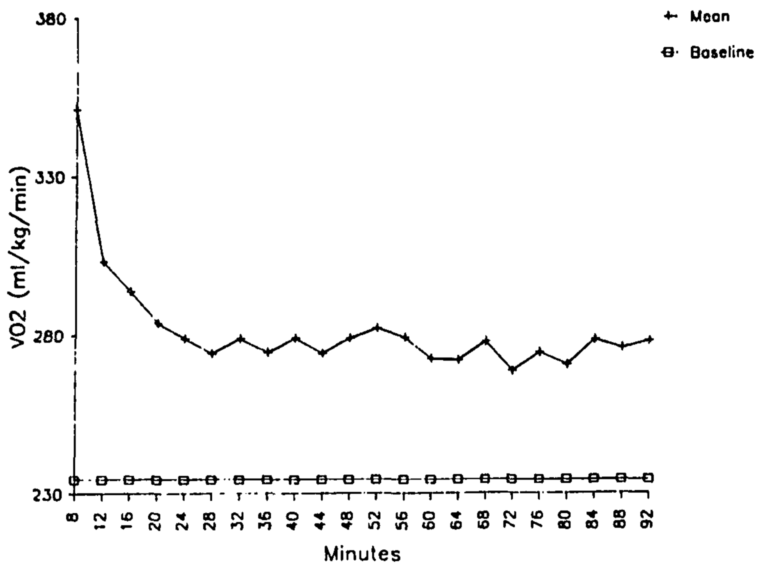


Figure 1. Mean Post-Exercise RMR Across Subjects.

Mean RMR Between Subjects

The initial ANOVA indicated that the treatment length had no effect on the RMR values obtained. A variation did exist between the subjects' post-exercise RMR. For this reason, another ANOVA, Repeated Measures statistical design was used to determine if a significant difference was present between any of the subjects across the four treatment days.

The independent variable for this design was treatment days with four levels. The dependent variable was the RMR value for the four post-test days. Descriptive statistics for the dependent variable for each subject on each day is represented in Appendix I.

An ANOVA was calculated using group and days as the independent variables. The differences observed in the RMR values following the exercise bout for each subject served as the dependent variable. The ANOVA (see Table 3) indicated the following:

1. No significant difference, $F = 0.98$, existed between the four treatment days ($F(3, 33) = 2.92$, $p < .05$).

2. A significant difference, $F = 12.19$, was present between the subjects ($F(11, 33) = 2.13$, $p < .05$).

Table 3

ANOVA Summary Table for RMR Values Across Subjects

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Treatment | 1677.17 | 3 | 559.06 | 0.98 |
| Subjects | 76494.17 | 11 | 6954.02 | 12.19* |
| Error | 18813.33 | 33 | 570.10 | |

*$F(11, 33) = 12.19$, $p < .05$

For the comparison of the mean RMR values for the 12 subjects, Tukey's HSD test for multiple comparisons was used to locate significant differences. The Tukey's HSD matrix is presented in Appendix J with the levels of significance acknowledged. The analysis of mean differences for the subjects indicated that significant difference in the RMR was apparent between a large number of the subjects.

Aside from individual differences in RMR that naturally prevail, it was assumed that some other factor was influencing the alterations seen in the RMR between subjects. It was for this reason that the next three ANOVAS were executed.

Mean Exercise Heart Rate Between Subjects

Descriptive data for the dependent variable, average exercising heart rate for each subject across the four post-test days are presented in Appendix K. An ANOVA, Repeated Measures statistical design was calculated using days, with four levels, as the independent variable. The differences observed in the mean exercising heart rate values during the exercise bout for each subject served as the dependent variable. The ANOVA (see Table 4) indicated the following:

1. A significant difference in mean exercising heart rate, $F = 3.47$, was found across the four post-test days ($F(3, 33) = 2.92$, $p < .05$).

2. A significant difference in mean exercising heart rate, $F = 25.40$, was found between the subjects ($F(11, 33) = 2.13$, $p < .05$).

Table 4

ANOVA Summary Table for Average Exercise Heart Rate Across the Four Post-test Days

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Treatment | 88.33 | 3 | 29.44 | 3.47* |
| Subjects | 2367.67 | 11 | 215.24 | 25.40** |
| Error | 279.67 | 33 | 8.47 | |

*$F(3, 33) = 2.92$, $p < .05$ **$F(11, 33) = 2.13$, $p < .05$

For comparison of the mean exercising heart rates, Tukey's HSD test for multiple comparisons was used to locate significant differences between the four post-test days (see Table 5). The analysis of mean differences for days indicated that:

1. No significant difference, $q = 1.83$, existed between days 4 and 2 ($F(4, 33) = 3.84$, $p < .05$).

2. No significant difference, $q = 2.0$, existed between days 1 and 2 ($F(4, 33) = 3.84$, $p < .05$).

3. A significant difference, $q = 3.83$, was found between days 3 and 2 ($F(4, 33) = 3.84$, $p < .05$).

4. No significant difference, $q = .17$, existed between days 1 and 4 ($F(4, 33) = 3.84$, $p < .05$).

5. No significant difference, $q = 2.0$, existed between days 3 and 4 ($F(4, 33) = 3.84$, $p < .05$).

6. No significant difference, $q = 1.83$, existed between days 3 and 1 ($F(4, 33) = 3.84$, $p < .05$).

A comparison was also carried out, using Tukey's HSD, to locate significant differences in the mean exercising heart rates between subjects. The results are similar to those uncovered for the comparisons between subjects when studying the dependent variable, mean RMR values across subjects. The Tukey matrix is located in Appendix L with significant cells recognized.

Table 5

Multiple Comparison of Mean Exercise Heart Rate
Across the Four Post-Test Days

| Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | 2.0 | 1.83 | 0.17 |
| 2 | 2.0 | - | 3.83* | 1.83 |
| 3 | 1.83 | 3.83* | - | 2.0 |
| 4 | 0.17 | 1.83 | 2.0 | - |

*$q(4, 33) = 3.84$, $p < .05$

Mean Percent Heart Rate Reserve Between Subjects

Heart rate was fairly indicative of differences that existed between the subjects' physical exertion during the four post-test days. However, variations were present in the target heart rate range established for each individual, therefore, a slight discrepancy might have resulted in the heart rate and the intensity level. To clarify each subject's level of intensity that was achieved during the four post-test days, another ANOVA Repeated Measures statistical design was carried out.

The descriptive data for the mean percentages of heart rate reserve utilized across the four post-test days for each subject are presented in Appendix M. In this design, the independent variable was days with four levels. The mean percent heart rate reserve served as the dependent variable. The ANOVA (see Table 6) indicated the following:

1. A significant difference in mean percentage of heart rate reserve, $F = 3.44$, was found across the four post-test days ($F(3, 33) = 2.92$, $p < .05$).

2. A significant difference in mean percentage of heart rate reserve, $F = 24.87$, was found between the subjects ($F(11, 33) = 2.13$, $p < .05$).

Table 6

ANOVA Summary Table for Mean Percentage of Heart Rate Reserve Across the Four Post-test Days

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Treatment | 54.52 | 3 | 18.17 | 3.44* |
| Subjects | 1443.38 | 11 | 131.22 | 24.87** |
| Error | 174.13 | 33 | 5.28 | |

*$F(3, 33) = 2.92$, $p < .05$ **$F(11, 33) = 2.13$, $p < .05$

For the comparison of the means associated with percentage of heart rate reserve, Tukey's HSD test for multiple comparisons was used to locate significant differences between the four post-test days. Table 7 exhibits the results of this comparison. The analysis of the differences indicated that:

1. No significant difference, $q = 1.43$, existed between days 4 and 2 ($F(4, 33) = 3.84$, $p < .05$).

2. No significant difference, $q = 1.38$, existed between days 1 and 2 ($F(4, 33) = 3.84$, $p < .05$).

3. A significant difference, $q = 3.01$, was found between days 3 and 2 ($F(4, 33) = 3.84$, $p < .05$).

4. No significant difference, $q = .14$, existed between days 1 and 4 ($F(4, 33) = 3.84$, $p < .05$).

5. No significant difference, $q = 1.58$, existed between days 3 and 4 ($F(4, 33) = 3.84$, $p < .05$).

6. No significant difference, $q = 1.44$, existed between days 3 and 1 ($F(4, 33) = 3.84$, $p < .05$).

Table 7

Multiple Comparison of Mean Percentage of Heart Rate Reserve Across the Four Post-Test Days

| Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | 1.58 | 1.44 | 0.14 |
| 2 | 1.58 | - | 3.01* | 1.43 |
| 3 | 1.44 | 3.01* | - | 1.58 |
| 4 | 0.14 | 1.43 | 1.58 | - |

*$q(4, 33) = 3.84$, $p < .05$

A comparison was also carried out, using Tukey's HSD, to locate significant differences in the mean percentage of heart rate reserve utilized between subjects. The results are similar to those discovered in the comparisons between subjects when studying the dependent variable, mean exercising heart rate values. The Tukey matrix is located in Appendix N with significant cells identified.

Mean Workload Between Subjects

Speculation was also made about the variability in the workload at which the individual subjects completed the exercise bout. Due to the large deviations that were present in the recorded workloads, the following ANOVA, Repeated Measures statistical design was performed.

The independent variable was days consisting of four levels. The dependent variable measured in this design was the average workload across the four post-test days. Descriptive data for this dependent variable are presented in Appendix O. The results of the ANOVA (see Table 8) revealed the following:

1. No significant difference in mean workload, $F = 1.04$, was found across the four post-test days ($F(3, 33) = 2.92$, $p < .05$).

2. A significant difference in mean workload, $F = 169.69$, was found between the subjects ($F(11, 33) = 2.13$, $p < .05$).

Table 8

ANOVA Summary Table for Mean Workload Utilized
Across the Four Post-test Days

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Treatment | 75.75 | 3 | 25.25 | 1.04 |
| Subjects | 45236.42 | 11 | 4112.40 | 169.69* |
| Error | 799.75 | 33 | 24.23 | |

*$F(11, 33) = 2.13$, $p < .05$

A comparison was completed, using Tukey's HSD, to locate significant differences in the mean workloads, used during the four post-test days, between subjects. The results are similar to those discovered in the comparisons between subjects when studying the dependent variable, mean exercising heart rate values . The Tukey matrix is located in Appendix P with significant cells identified.

Mean RMR for Groups Based Upon Percentage of Heart Rate Reserve

At this point, it was evident that numerous factors such as the percentage of heart rate reserve that subjects exercised at on post-test days, or workload that was utilized on post-test days, might influence the RMR values recorded for that day. To test this hypothesis, an ANOVA, Split Plot Factorial statistical design was again performed. The subjects were divided into two groups which are presented in Table 9. The average percentage of heart rate reserve was used as the determining factor for splitting subjects into high and low groups.

Table 9

Two Groups Based on Percentage of the Heart Rate Reserve Value

| Group 1 | | Group 2 | |
|---|---|---|---|
| Subject | % HRR | Subject | % HRR |
| S1 | 82.77% | S2 | 72.87% |
| S3 | 84.04% | S4 | 80.43% |
| S8 | 83.96% | S5 | 69.73% |
| S10 | 83.90% | S6 | 73.68% |
| S11 | 83.14% | S7 | 69.96% |
| S12 | 82.95% | S9 | 76.64% |

The independent variables for this particular design were the groups with two levels and the time with 23 levels. Again, the first time level represented the baseline RMR established by pretesting. The remaining 22 time frames were intervals of four minutes, beginning at the eight minute mark following the cessation of the exercise bout. The dependent variable was the RMR values. The ANOVA (see Table 10) indicated the following:

1. No significant difference in the RMR, $F = .77$, was found between the two groups ($F(1, 10) = 4.96$, $p < .05$).

2. A significant difference in the RMR, $F = 15.55$, was observed between the time intervals ($F(22, 220) = 1.62$, $p < .05$).

3. No significant difference in the RMR, $F = .55$, was found for the interaction of time and group, ($F(22, 220) = 1.62$, $p < .05$).

Table 10

ANOVA Summary Table for Mean Percentage of Heart Rate Reserve Across the Two Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 29450.00 | 1 | 29450.00 | 0.77 |
| Error | 383388.56 | 10 | 38338.86 | |
| Within Subjects | | | | |
| Time (T) | 100619.47 | 22 | 4573.61 | 15.55* |
| T X G | 3539.08 | 22 | 160.87 | 0.55 |
| Error | 64695.28 | 220 | 294.07 | |

*$F(22, 220) = 1.62$, $p < .05$

Multiple comparison was not executed to determine the level of significant differences in the time interval. Since no other significant difference was found in this design, it was assumed that location of the mean RMR values across time were in the same area as those found in the initial ANOVA. Refer to Appendix H.

It appeared as if no significant difference in the two groups resulted because the mean percentage of heart rate reserve utilized during the four post-test days was similar for both groups. Figure 2 indicated that a difference did occur between the two groups, although the difference was not significant.

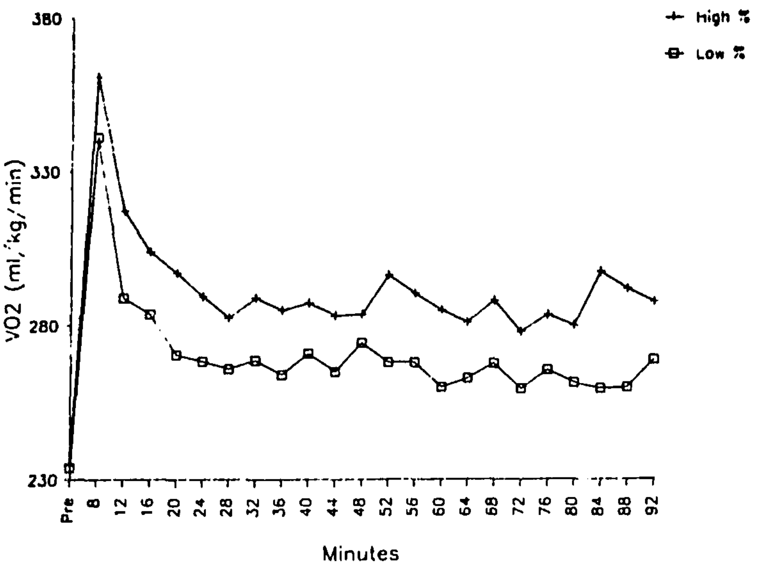


Figure 2. Mean Post-Exercise RMR Across Two Groups Based Upon Percentage of Heart Rate Reserve.

Taking this into account, the subjects were divided into four groups (see Table 11) so that the average percent heart rate reserve utilized would be more diverse between the groups. The drawback to this approach was the limited number of subjects that were placed in each group.

Table 11

Four Groups Based on Percentage of the Heart Rate Reserve Values

| Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|---|---|---|---|---|---|---|---|
| Sub. | %HRR | Sub. | %HRR | Sub. | %HRR | Sub. | %HRR |
| S3 | 84.04% | S1 | 82.77% | S4 | 80.43% | S2 | 72.87% |
| S8 | 83.96% | S11 | 83.14% | S6 | 73.68% | S5 | 69.73% |
| S10 | 83.90% | S12 | 82.95% | S9 | 76.64% | S7 | 69.96% |

Another ANOVA, Split Plot Factorial statistical design was executed with the latest grouping technique. The independent variables for this particular design were groups with four levels and time with 23 levels. Time was measured exactly like that described previously. The dependent variable was again the mean RMR values. The ANOVA (see Table 12) indicated the following:

1. No significant difference in the RMR, $F = .58$, was found between the four groups ($F(3, 8) = 4.07$, $p < .05$).

2. A significant difference in the RMR, $F = 14.28$, was observed between the time intervals ($F(22, 176) = 1.66$, $p < .05$).

3. No significant difference in the RMR, $F = .56$, was found for the interaction of time and group, ($F(66, 176) = 1.43$, $p < .05$).

Table 12

ANOVA Summary Table for Mean Percentage of Heart Rate Reserve Across the Four Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 73881.11 | 3 | 24627.04 | 0.58 |
| Error | 338957.45 | 8 | 42369.68 | |
| Within Subjects | | | | |
| Time (T) | 100619.47 | 22 | 4573.61 | 14.28* |
| T X G | 11857.80 | 66 | 179.66 | 0.56 |
| Error | 56376.55 | 176 | 320.32 | |

*$F(22, 176) = 1.66$, $p < .05$

Multiple comparison was not carried out to determine the location of significant differences between the time intervals, however, Appendix H gives some indication of where the differences occur.

Mean RMR for Groups Based Upon Body Composition

Another approach was taken in dividing subjects into testing groups for analysis. Body composition, or more specifically the percent of fat free mass an individual possesses has been identified as a contributor to the RMR level. Initially, the subjects were divided into two groups according to their percent body fat. Refer to Table 13.

Table 13

Two Groups Based on Body Composition

| Group 1 | | Group 2 | |
|---|---|---|---|
| Subject | % Body Fat | Subject | % Body Fat |
| S1 | 18.0% | S2 | 32.9% |
| S3 | 25.7% | S5 | 29.5% |
| S4 | 23.2% | S7 | 33.9% |
| S6 | 18.8% | S8 | 27.5% |
| S9 | 17.0% | S11 | 27.0% |
| S10 | 24.5% | S12 | 28.3% |

An ANOVA, Split Plot Factorial design was used to compare the mean RMR values between the two groups. The independent variables were group and time and the dependent variable was again RMR. The ANOVA (see Table 14) indicated the following:

1. No significant difference in the RMR, $F = .83$, was found between the four groups ($F(1, 10) = 4.96$, $p < .05$).

2. A significant difference in the RMR, $F = 15.52$, was observed between the time intervals ($F(22, 220) = 1.62$, $p < .05$).

3. No significant difference in the RMR, $F = .52$, was found for the interaction of time and group, ($F(22, 220) = 1.62$, $p < .05$).

Table 14

ANOVA Summary Table for Body Composition
Across the Two Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 31594.96 | 1 | 31594.96 | 0.83 |
| Error | 381243.60 | 10 | 38124.36 | |
| Within Subjects | | | | |
| Time (T) | 100619.47 | 22 | 4573.61 | 15.52* |
| T X G | 3399.79 | 22 | 154.54 | 0.52 |
| Error | 64834.57 | 220 | 294.70 | |

*$F(22, 220) = 1.62$, $p < .05$

Multiple comparison was not carried out to determine the location of the significant differences between time intervals, however, Appendix H gives some indication of where the differences occur.

Figure 3 demonstrated that a difference was present between the two groups; however, the difference was not significant.

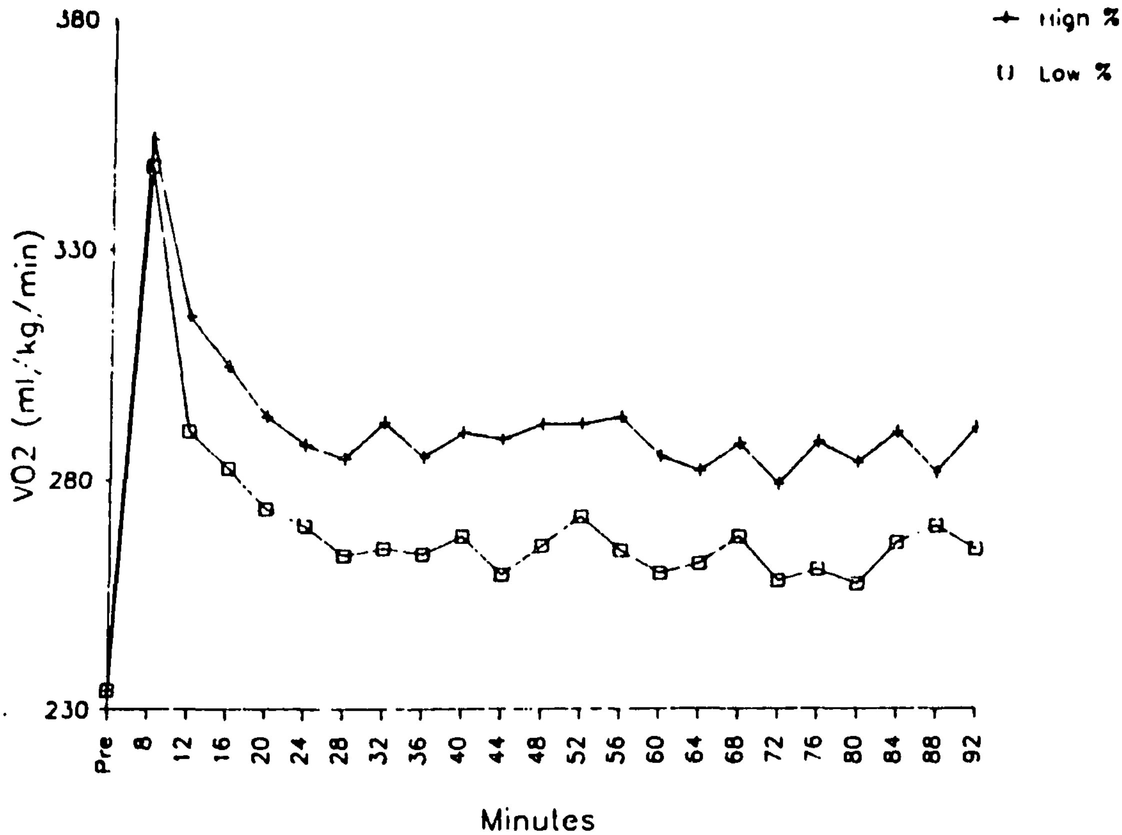


Figure 3. Mean Post-Exercise RMR Across Two Groups Based Upon Body Composition.

Since no statistically significant differences were observed between the two groups, the groups were divided into four groups in order to create more diversity between the average percent body fat for each group. Table 15 presents the four groups. The drawback to this approach was the limited number of subjects that were placed in each group.

Table 15

Four Groups Based on Body Composition

| Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|---|---|---|---|---|---|---|---|
| Sub. | % Body Fat | Sub. | % Body Fat | Sub. | % Body Fat | Sub. | % Body Fat |
| S1 | 18.0% | S3 | 25.7% | S8 | 27.5% | S2 | 32.9% |
| S6 | 18.8% | S4 | 23.2% | S11 | 27.0% | S5 | 29.5% |
| S9 | 17.0% | S10 | 24.5% | S12 | 28.3% | S7 | 33.9% |

Another ANOVA, Split Plot Factorial statistical design was executed with the latest grouping technique. The independent variables for this particular design were groups with four levels and time with 23 levels. Time was measured exactly like that described previously. The dependent variable was again the mean RMR values. The ANOVA (see Table 16) indicated the following:

1. No significant difference in the RMR, $F = .37$, was found between the four groups ($F(3, 8) = 4.07$, $p < .05$).

2. A significant difference in the RMR, $F = 14.65$, was observed between the time intervals ($F(22, 176) = 1.66$, $p < .05$).

3. No significant difference in the RMR, $F = ..65$, was found for the interaction of time and group, ($F(66, 176) = 1.43$, $p < .05$).

Table 16

ANOVA Summary Table for Body Composition
Across the Four Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 49888.74 | 3 | 16629.58 | 0.37 |
| Error | 362949.83 | 8 | 45368.73 | |
| Within Subjects | | | | |
| Time (T) | 100619.47 | 22 | 4573.61 | 14.65* |
| T X G | 13304.18 | 66 | 201.58 | 0.65 |
| Error | 54930.17 | 176 | 312.10 | |

*$F(22, 176) = 1.66$, $p < .05$

Multiple comparisons were not performed since the only significant finding dealt with the time intervals. Appendix H represents the time interval matrix that was established for the initial ANOVA and it was assumed that no significantly different results would exist.

Mean RMR for Groups Based Upon Workload Utilized

Due to the extreme variations in the mean workloads used by the subjects, groups were formed according to high and low workload levels. Refer to Table 17.

Table 17

Two Groups Based on Mean Workload Values

| Group 1 | | Group 2 | |
|---|---|---|---|
| Subject | Workload | Subject | Workload |
| S1 | 143.5 | S2 | 122.25 |
| S3 | 131.75 | S4 | 91.0 |
| S6 | 179.5 | S5 | 73.0 |
| S10 | 138 | S7 | 88.75 |
| S11 | 143.75 | S8 | 97.75 |
| S12 | 151.5 | S9 | 93.75 |

An ANOVA, Split Plot Factorial design was used to compare the mean RMR values between the two groups. The independent variables were group and time and the dependent variable was again RMR. The ANOVA (see Table 18) indicated the following:

1. No significant difference in the RMR, $F = 1.30$, was found between the two groups ($F(1, 10) = 4.96$, $p < .05$).

2. A significant difference in the RMR, $F = 17.50$, was observed between the time intervals ($F(22, 220) = 1.62$, $p < .05$).

3. A significant difference in the RMR, $F = 1.87$, was found for the interaction of time and group, ($F(22, 220) = 1.62$, $p < .05$).

Table 18

ANOVA Summary Table for Mean Workload
Across the Two Groups

| Source | S.S. | df | M.S. | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Groups (G) | 47505.95 | 1 | 47505.95 | 1.30 |
| Error | 365332.62 | 10 | 36533.26 | |
| Within Subjects | | | | |
| Time (T) | 100619.47 | 22 | 4573.61 | 17.50* |
| T X G | 10734.80 | 22 | 487.95 | 1.87** |
| Error | 57944.55 | 220 | 261.36 | |

*$\underline{F}(22, 220) = 1.62$, $\underline{p} < .05$ **$\underline{F}(22, 220) = 1.62$, $\underline{p} < .05$

Figure 4 was presented to indicate that even though a significant difference was not found between groups, a trend existed. Multiple comparison was not executed to determine the location of difference for the time interval. Appendix H reveals results that are expected to be similar.

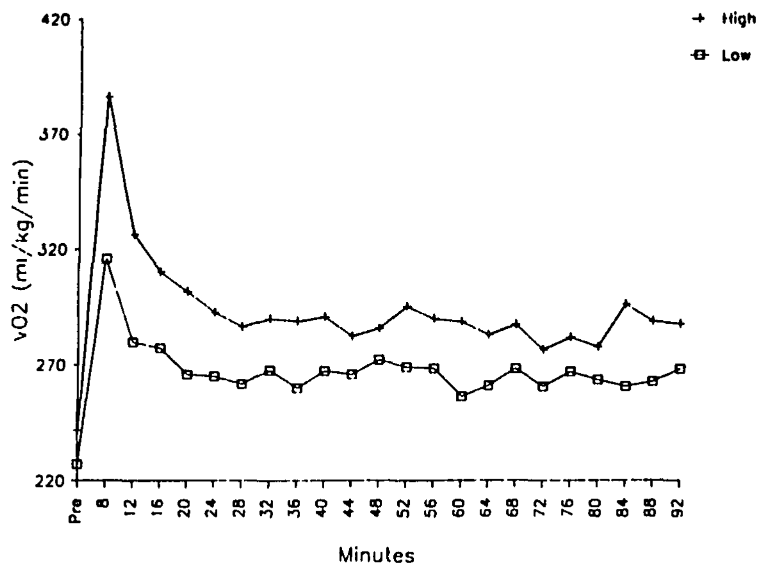


Figure 4. Mean Post-Exercise RMR Across Two Groups Based Upon Average Workload.

## Discussion

The subjects in this study were college age females of low to moderate fitness levels. Measurement of body fat values indicated a range from 17 percent to 33.9 percent. In respect to the parameters monitored initially, the population was fairly homogeneous, therefore the results should be applicable to the majority of college age females.

Groups were established with regard to percent body fat and the date of the onset of the menstrual cycle. Both of these variables have been determined to influence the RMR of an individual, therefore, to negate any biases, the groups were matched proportionately.

All subjects underwent identical pre- and post-test procedures. The only differing factor between groups was the length of the exercise training period. Group A, Group B, Group C, and Group D exercised three times a week for 30 minutes each session at an intensity level of 70 to 85 percent for one, two, four, and five weeks, respectively.

Mean RMR Across the Experimental Groups

The variability in the RMR due to the length of the exercise period did not prove to be statistically significant. The means for the four groups were as follows: (a) Group A, 305.72; (b) Group B, 247.41; (c) Group C, 278.83; and (d) Group D, 295.87. Although the values appear to be considerably diverse, the $F$ ratio did not prove to be statistically significant. Figure 1 showed that the mean RMR values of the four groups differed; however, the results had no pattern regarding the length of the training period. One possible reason for this, could have been the fact that only the acute RMR following exercise was tested. The length of the training period did not affect the acute RMR as much as it might have affected the chronic RMR. The acute RMR results from measuring the $VO_2$ immediately following an exercise bout. The chronic RMR would be tested by determining a new baseline RMR value following a resting period. It would seem logical that the permanent RMR would be affected by the length of the training period more than would be the acute RMR.

There was a significant difference between the time intervals studied during the post-test measurement period. The baseline RMR value was significantly different from all of the 22 time frames measured following the exercise. The first reading following the exercise was also significantly different from all other times recorded. Both of these findings were expected. It was the experimental hypothesis of this study that an aerobic exercise of the proper intensity would produce a prolonged elevation in the RMR. The fact that the RMR fell quickly for the first eight to 12 minutes indicates the rapid component of the recovery process. Brehm and Gutin (1986) found that the MR drops quickly for two to five minutes following exercise and then assumes a more gradual decline until resting levels are reached.

A number of reasons have been cited as to why such discrepancies exist from study to study concerning this topic. Freedman-Akabas et al. (1985) reported that variability in eating patterns, stress levels, and one's tendencies to participate in activities all make interpretation of the RMR difficult. Felts et al. (1988) added that different exercise tasks, protocols, sampling techniques and times might all limit the amount of transfer that exists between studies. Bahr et al. (1987) stated that variations in experimental design make it impossible to draw any conclusions as to the magnitude of the EPOC.

One or all of these variations were present in the studies that were reviewed for this paper. Elliot et al. (1988) disagreed with the results found in this study. The results indicated that the MR of the subjects had returned to baseline levels after just 30 minutes; however, the reason may be as easy to explain as defining the resting level that was used in the study. The baseline was established with only eight minutes of supine rest. This could result in an overestimation of the true RMR which would mean that the values reported following the exercise were still elevated above the true RMR levels, but no longer significantly elevated above the resting levels established.

Freedman-Akabas et al. (1985) failed to find a significant increase in the MR after just 40 minutes following the cessation of the exercise. One factor that might have resulted in this finding was the fact that the subjects in this study exercised at their anaerobic threshold (AT). This level for most individuals is approximately 50 to 60 percent of their maximal effort. It is generally agreed that subjects must exercise at an intensity greater than this in order to experience a prolonged elevation in the MR. Bahr et al. (1987) stated that exercise of 70 percent is known to completely deplete glycogen stores, which is one of the reasons given for EPOC. Unless these stores are depleted, a smaller amount of energy is required to replenish them, which results in a decrease in the magnitude and duration of the EPOC. Hagberg et al. (1980) reported that an intensity somewhere between 65 and 80 percent was sufficient to elicit an increase in the MR. The investigators did not test the 70 percent mark; however, 70 percent was the estimation.

Freedman-Akabas et al. (1985) reported that after exercising subjects for a longer duration and at a higher intensity level, no significant increase in the MR at the 40-minute time frame was evident. It is hard to question this, since no duration or intensity level was stated, only that they were longer and higher, respectively. It is assumed, however, that only the more fit individuals participated in these more intense experiments performed by Freedman-Akabas et al. Hagberg et al. (1980) pointed out that adaptations to endurance exercise training may enable an individual to adjust to the energy requirement of constant load submaximal work more rapidly, therefore, the MR may fall quicker for the trained subjects that performed the more intense exercise bouts.

Maehlum et al. (1986) agreed with the findings that resulted from the present study. The results revealed that the MR remained elevated for 24 hours following the cessation of the exercise. The parameters appear to have been studied carefully with highly reliable equipment. The only question surrounding this study was the length of the exercise treatment. The intensity level was 70 percent, which is not unreasonable; however, the duration was 80 to 90 minutes which might be considered too long for the average individual who desires to work out for weight management reasons.

Obviously, numerous factors must be taken into account when trying to compare the results from several studies to each other. Some researchers believe that if an individual needs to exercise to control weight, then they will be unable to exercise at an intensity level high enough to elicit a prolonged increase in the MR. However, it is important to realize that the pace or the type of exercise utilized does not bring about the same results in every individual. For an overweight person, a very slow pace may be accompanied by a high intensity level. Eventually, if an obese subject performs a regimen at 70 percent intensity, the pace or the type of exercise will have to be altered to reproduce the 70 percent intensity level. At this point, it might be that the person has lost some weight and is capable of participating in a more demanding activity. In any case, if a person exercises at 70 percent of maximal effort, regardless of the mode of activity, the individual will experience gains that are beneficial to weight problems. Pace and time per mile should not be used when determining what brings about a prolonged increase in the MR. Intensity level should always be one of the independent variables manipulated.

Mean RMR Between Subjects

Although no statistically significant differences were observed between the initial experimental groups, differences did exist between the individual subjects regardless of group affiliation. Many things could account for the differences that were revealed in the RMR values between the subjects. Individual differences naturally occur due to body size, lifetime activity patterns, fat-free mass, and even genetics. Bogardus et al. (1986) reported that family membership accounted for approximately 11 percent of the variance seen in RMR values. In 1988, Owen stated that the variables most highly correlated with measured RMR values included: (a) weight, (b) body surface area, (c) lean body mass, (d) body cell mass, and (e) fat-free mass. It was possible that the differences seen between the individuals were simply due to these type of variables that were uncontrollable in the context of a study of this nature.

However, it was also possible that the differences that were observed were due to some of the parameters that were controlled in this particular study. Current literature supports the belief that the exercise intensity must be at least 70 percent before a marked increase in EPOC will occur. The duration of the activity has also been questioned. Findings reveal that 20 minutes of continuous exercise will lead to a prolonged elevation with greater increases experienced as the duration lengthens (Bahr et al., 1987). The duration was the same for all subjects in this study (30 minutes), therefore, this was not considered a contributing factor to the differences seen in the magnitude of the EPOC. However, it was long enough, according to the literature, to cause an increase.

Body composition is also known to influence the RMR values measured. Only absolute values of RMR, which is what was measured in this study, differ between obese subjects and their leaner counterparts. Elliot et al. (1989) reported that when the RMR of obese subjects are normalized for the amount of fat-free body weight, the values are comparable across both obese and control subjects.

The controllable parameters were analyzed further to determine their role in the response of the RMR that was observed due to the exercise stimulus.

Mean Exercise Heart Rate and Percentage of Heart Rate Reserve Utilized Between Subjects

The ANOVA, Repeated Measures design that was executed to determine whether or not a significant difference existed between the mean exercising heart rate and the subjects revealed that a significant difference was present between the subjects. This was not uncommon in a normal setting; however, the limits placed upon the heart rate (in terms of intensity) would have appeared to inhibit this difference to some degree. Apparently, the range of 70 to 85 percent of the subject's heart rate reserve allowed enough leeway for a significant difference to occur.

It is important to recognize that the heart rate and the percentage of heart rate reserve exercised utilized, are not always indicative of each other. The Karvonen formula, used to establish the heart rate limits, takes into account some very individualized variables including resting heart rate and age. Since the subjects for this study were approximately the same age the determining factor that created the differences in target heart rate range established was the resting heart rate which varied from individual to individual. Although the mean exercising heart rate was identical for some subjects, the mean percentage of the heart rate reserve was not the same. For this reason, another ANOVA comparing the percentage of heart rate reserve exercised at, across the post-test days and the subjects was performed. As expected, a significant difference did result between the subjects.

Mean Workload Between Subjects

The intensity measured by the mean exercising heart rate or the percentage of heart rate reserve utilized, did not always reveal how hard each subject was actually working. It also did not disclose the fitness level of any of the subjects due to the fact that the intensity level was somewhat predetermined. While everyone was within the 70 to 85 percent of heart rate reserve range, the workload necessary for pushing each individual into that range was not the same across subjects. It was also obvious that some subjects improved individual fitness levels during the study, particularly the individuals in Groups C and D. In the initial stages of the training, the subjects exercised at an intensity level of 70 to 85 percent of maximal heart rate reserve. In the final stages of the training, the subjects still exercised at an intensity level of 70 to 85 percent of their max; however, the workload required for obtaining this level had increased with the training. This could have possibly affected the magnitude of the EPOC observed in the post-testing procedures. Hagberg et al. (1980) reported that as an individual becomes more physically fit, the magnitude and duration of the recovery period, particularly the slow component, is reduced. This might have been the reason for the insignificant differences observed between the initial experimental groups. Another ANOVA, Repeated Measures design was executed to determine if a significant difference existed between the workload used by each subject between the subjects. It appeared obvious that a significant difference was present, but the ANOVA proved that a statistically significant difference was present.

Mean RMR for Various Grouping Techniques

At this point, it was known that the RMR varied across subjects as well as did the mean workload, mean exercising heart rates, and the mean percentage of heart rate reserve utilized during the post-test days. With this information, it was the goal of this researcher to identify the parameter that was most responsible for the variations that existed between the subject's RMR values. To do this, the subjects were divided into various groups dependent upon their individual recordings for the previously described parameters.

The first division was based upon the percentage of heart rate reserve used by each subject. Only two groups were formed: one with the six highest percentages and one with the six lowest percentages. This ANOVA resulted in statistically insignificant differences between the two groups. This outcome might have occurred due to the minute differences in the group averages for this parameter. Less than 10 percent separated the two groups. Regardless of the insignificant differences found in the ANOVA, a tendency still existed that indicated that exercising at the upper limit (85%) would be more beneficial for increasing the magnitude of the EPOC. Figure 2 is a graph of the average RMR values for the two groups. While the difference may not have been significant, there was a distinct difference.

A second ANOVA was completed using this variable; however, four groups were created. By doing this, it was presumed that the differences that were present between the group averages would be greater. The only drawback to this grouping technique was the small number of individuals placed in each group. The extremely small $\underline{N}$ made it necessary for the $\underline{F}$ ratio to be much larger before a significant difference could be reported. Unfortunately, the $\underline{F}$ ratio was not significant and the size of the groups was considered to be responsible for this finding.

The next characteristic used for grouping purposes was body composition. The subjects were divided into two groups of the six individuals with the highest percent body fat and the six individuals with the lowest percent body fat. The ANOVA for this design also resulted in no significant differences between the two groups. Again the average percent body fat for both groups was not that diverse. Approximately eight percent separated the two groups. Figure 3 indicated that a small distinction was evident between the two groups even though the value was not significant. The graph shows that the high group possessed the largest RMR values during the recovery period. However, the RMR values reported are absolute values only and the literature reported that the absolute values for larger individuals are greater than those observed for smaller people. If relative values had been computed, the hypothesis would be that the two groups reacted in the same way to the exercise stimulus. To create more diversity, four groups were created with the difference between the highest and lowest groups being 14.2 percent. The problem of the small N was again apparent in this design. Due to this limitation, no significant differences were discovered between the four groups.

Finally, the groups were divided according to the workload, at which the exercise was performed, on the four post-test days. For this analysis, only two groups were necessary because the variation between the two groups was as much as what could have been achieved dividing the subjects into four groups. The average workload for the high group was 148 watts and that for the low group was 94.4 watts. The ANOVA for this design resulted in no significant difference between the two groups. A significant difference was observed between the time intervals. A significant difference was found for the interaction effect between group and time as well. Figure 4 showed the differences that existed between the subjects that worked at a higher workload and the subjects that worked at a lower workload. Although the difference was not significant, a noteworthy difference did occur. The interaction effect appeared due to the fact that at some time interval one group increased while the other group decreased.

An interesting discovery was made with this grouping technique. All of the other grouping procedures resulted in equivalent groups, with respect to the baseline RMR value calculated. In this procedure, the group that formulated the high group possessed a higher baseline RMR value than those subjects in the low group. This indicated that the subjects in the high group were in better condition at the beginning of the study, therefore, a higher workload was required to elevate the heart rate into the target heart rate range. As the condition level improves, the required workload necessary for reaching the suggested 70 percent intensity level increases; and, although, no significant difference occurred between the groups, the trend was apparent that higher workloads elicited an increase in the magnitude of the EPOC.

## CHAPTER V

## SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

### Summary

This study was undertaken to determine what effect aerobic exercise, that was performed at 70 to 85 percent of the heart rate reserve for a duration of 30 minutes, has on the subject's RMR. The magnitude of the increase in RMR following exercise, as well as the duration of that increase were both investigated.

Twelve college age females were divided into four groups. Initially, 13 subjects were participating in the study; however, one subject had to withdraw following pretesting. Groups were established so that the mean percent body fat for each group was comparable (26.35 $\pm$ .25%). Body fat was measured via hydrostatic weighing. The date of the onset of the menstrual cycle was also utilized in forming the groups. Ideally, all subjects in a group experienced their period at the same time, and this time frame did not correspond to the testing week for that particular group.

Everything was identical for the four groups, except the length of the training phase. Group A exercised for one week, Group B exercised for two weeks, Group C exercised for four weeks, and Group D exercised for five weeks. Training consisted of cycling on a Bosch cycle ergometer three times a week, for 30 minutes, at an intensity of 70 to 85 percent of the subjects heart rate reserve. Heart rate in beats per minute (bpm) and workload in watts were recorded every six minutes during exercise. Heart rate was measured continuously throughout the exercise period by an electronic heart monitor. Following exercise, subjects were required to cool down until their heart rate reached a level below 120 bpm.

Pretesting took place the week prior to the beginning of the training phase. All subjects participated in pretesting at the same time. Testing took place on four consecutive days in order to eliminate any daily changes in RMR that might occur due to stress, diet, or other behavior patterns. Activity was supposed to be held to a minimum for the testing period. Diet was not restricted; however, subjects were informed of the alterations that can occur in RMR due to changes in diet. All subjects were asked to consume similar diets, in respect to quantity and quality, during the testing periods. Subjects were required to spend 20 minutes resting, in the presence of the investigator, before measurement began. Measurement of RMR was performed on a Beckman Metabolic Cart (MMC). Both oxygen and carbon dioxide were analyzed. The MMC was calibrated following every third subject in this phase. During measurement, subjects lied supine on a hospital gurney for 30 minutes. Readings were collected every two minutes throughout the entire process. High and low values were not accounted for, and the remaining 35 to 40 readings were averaged. The resulting value was considered the RMR baseline.

Post-testing took place the week immediately following the training period. Post-testing was carried out on four consecutive days for reasons previously discussed. The same factors were taken into consideration in the post-test that had been in the pretest. Excess exercise was discouraged and diet was monitored by the subjects. Post-testing of RMR took place following an exercise bout and lasted for 90 minutes. The initial reading was gathered eight minutes following the cessation of exercise, with consecutive readings occurring every four minutes. For this test, the MMC was calibrated between every subject.

Various statistical procedures were carried out on the raw data that was gathered. An Analysis of Variance, Split Plot Factorial statistical design with fixed effects was used on six different analyses. When significant differences resulted, Tukey's HSD Multiple Comparison Test was applied to determine significant differences between the means. The independent variables for this design included groups with varying levels and time with 23 levels. The first level for the time represented the RMR baseline followed by 22 successive four minute time intervals. The dependent variable for this design was the recorded RMR values.

A simple ANOVA, Repeated Measures statistical design was completed post hoc. The independent variables for these analyses included one group with 12 levels and testing days with four levels. This analysis was carried out four times with the following dependent variables: (a) RMR, (b) mean heart rate, (c) mean percent heart rate reserve, and (d) workload.

## Findings

Significance for the findings of this study was determined at the .05 level. The ANOVA and multiple comparison tests indicated the following:

1. Metabolic rates become significantly elevated with exercise at the 70 to 85 percent intensity level, and remain elevated for at least 90 minutes after exercise.

2. The elevation in the post-exercise RMR that resulted was independent of the length of the training period.

3. The dependent variables--mean exercise heart rate, workload, RMR, and percentage of heart rate reserve utilized--were significantly different between the subjects regardless of group affiliation.

4. None of the parameters--mean exercise heart rate, workload, RMR, or percentage of heart rate reserve--significantly influenced the RMR.

5. Trends did exist between percentage of heart rate reserve utilized during the post-test days and the recorded RMR values.

## Conclusions

It was the belief of this researcher that the type of aerobic exercise applied in this study was of sufficient intensity and duration to create an increase in the MR above resting values for a period no less than 90 minutes. This appears to be a slight underestimate, as well, since none of the values had returned to resting levels by the end of the testing period. With this realization, it was determined that proper aerobic exercise can have beneficial consequences to the individual who participated in them, not only during the activity but in the time following the cessation of the activity as well.

Individuals who are participating in an exercise program solely for the weight loss benefits that are derived from the activity, should experience some positive feedback associated with their effort. The best approach is to monitor energy intake and increase energy expended. Weight loss can occur by simply restricting caloric intake; however, exercise cannot be omitted if the lose of adipose tissue is the desired end. Exercise helps to maintain the lean body mass which in turn helps to preserve the RMR. If the RMR declines, (as with severe caloric restriction) the individual will have to continually fight to keep the weight from returning.

It is important to realize that energy required to perform an activity varies from individual to individual. A person who needs to exercise to lose weight, can exercise at a high enough intensity to experience the phenomena reported in this study. The workload that would be employed might be extremely less than that used by a more fit individual; however, the intensity level might be right on target. Intensity and duration are the keys. The duration should be at a minimum of 20 minutes and the intensity should be at least 70 percent. Whatever workload or pace is required to achieve this intensity level will be individualized and sufficient.

In conclusion, if the intensity, duration, and frequency of an aerobic activity are appropriate, significant benefits can be experienced long after the activity has ended.

## Recommendations

Several things were learned from conducting this study. It appears that exercise at the 70 percent intensity level can have increased benefits beyond those experienced during the activity itself. Exercise alone may not be enough in the treatment of obesity; however, a monitored diet and proper exercise could be the only life long natural method yet discovered.

The majority of the subjects stated that the study was enjoyable and gave them a reason to exercise. Many noticed increased feelings of strength and stamina, and most expressed a desire to continue some type of aerobic activity. Fitness levels were improved in the subjects placed in the groups who completed four or five weeks of the training period. This was evidenced by the increased workloads coupled with lower working heart rates and faster recovery times.

Future studies in this area may want to attempt some of the following:

1. Monitor caloric intake to ensure that variations in diet do not influence the study.

2. Delimit the study to a single fitness-leveled groups so that the question of fitness level can be negated.

3. Monitor body composition at the end of the study to determine whether or not any improvement has been made in that area. By doing this, relative RMR values can be obtained and differences between more obese subjects and leaner subjects can be compared.

4. Establish a new RMR following a resting period at the end of the study to determine whether or not the aerobic training resulted in a permanent change in the RMR.

5. Employ more subjects for each group, if time permits, to determine a more accurate analysis of the dependent variables responsible for the elevated MR following the exercise.

6. Monitor exercise intensity level, and establish personal levels for each subject.

## Appendix A

## Human Subjects Institutional Review Board Acceptance Form

Human Subjects Institutional Review Board

Kalamazoo Michigan 49008-3899

# WESTERN MICHIGAN UNIVERSITY

Date: December 13, 1989

To: Marti Davis

From: Mary Anne Bunda, Chair Mary Anne Bunda

This letter will serve as confirmation that the changes in your research protocol, "The Effects of Aerobic Conditioning Upon the Resting Metabolic Rate", as submitted in the memo of December 12, 1989, have been approved as by the HSIRB. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the approval application. You must seek reapproval for any change in this design.

The Board wishes to thank you for seeking reapproval for your research.

xc: M. Dawson, HPER

HSIRB Project Number 89-09-11

Appendix B

Informed Consent

## APPENDIX B

### Informed Consent

This study is being performed so that a better comprehension of the effects that aerobic exercise have on an individual's resting metabolic rate will be gained. The actual exercise sessions will be performed on a cycle ergometer. The study will take place for an eight week period starting January 15 and extending until March 19, 1989. Subjects will be required to exercise for 30 minutes each session for three times each week.

The first thing that the subjects will learn is how to figure their own target heart rate. By using Karvonen's formula, the workload that the subjects will work at for the remaining sessions will be calculated. The percentages that will be used with the formula will be 70% and 85%. This will establish the range that the subject's heart rate will stay within while they exercise on the bicycle. The subject's metabolic rate will be measured with a metabolic cart. This is simply an instrument that analyzes the subject's expired air. With the use of this instrument, the resting metabolic rate of the subjects will be calculated and the results will show what happens to the resting metabolic rate as the subject improves their cardiovascular fitness. Subjects will also have their percent bodyfat measured at the beginning of the study by way of hydrostatic weighing. If the subject is uncomfortable with the hydrostatic method, callipers can be used, but the accuracy of this method is not as high as the hydrostatic method.

The subjects will be at no greater risk than they would encounter if participating in their own exercise program. In fact, due to warm-up and cool down procedures required, subjects will be exposed to even less risk than they would be on their own.

Subjects will receive the knowledge gained from this study. They will also be made aware of proper exercise guidelines and fitness components. This study can possibly give people the incentive and knowledge required to keep them interested in a lifelong lifestyle.

Subject's names will be withheld from the written report to protect the subject's confidentiality.

If there are any questions concerning this study that an individual is unclear about, feel free to contact me, Marti R. Davis, at 375-XXXX or Dr. Mary Dawson at 387-XXXX. Subjects should be in complete understanding of the procedures and responsibilities that are associated with this study.

At any time during the study, if an individual desires to withdraw from the program, there will be no pressure placed on them to stay. Participation in this study is completely voluntary and may be terminated at any time without penalty. In the event that medical attention is required, subjects will be responsible for their own treatment.

____ Check here if you have seen the metabolic cart demonstrated.

(DO NOT SIGN THIS FORM UNTIL YOU HAVE SEEN THE DEMONSTRATION)

____________________ ____________________

Signature Date

Appendix C

Experimental Groups

# APPENDIX C

Experimental groups

| Groups | Average % body fat | Treatment period | Subjects |
|---|---|---|---|
| Group A | 26.6 | 1 week | 1<br>2<br>— |
| Group B | 26.1 | 2 weeks | 4<br>5<br>6 |
| Group C | 26.1 | 4 weeks | 7<br>8<br>9<br>10 |
| Group D | 26.6 | 5 weeks | 11<br>12<br>13 |

Note. — indicates subject withdrew from study early

Appendix D

Participation Dates

# APPENDIX D

Participation Dates

| No. | Participation Dates Feb. 7 | 8 | 9 | 10 | 12 | 14 | 16 | 19 | 21 | 22 | 23 | 24 | 26 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | X | X | X | X | X | X | X | - | - |
| 2 | X | X | X | X | X | X | X | X | X | X | X | X | - | - |
| 3 | X | X | X | X | X | X | X | X | X | - | X | - | S | X |
| 4 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |
| 5 | X | X | X | X | X | X | X | X | X | - | X | - | S | X |
| 6 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |
| 7 | X | X | X | X | X | X | X | X | X | - | X | - | X | S |
| 8 | X | X | X | X | X | X | X | X | X | - | S | - | X | X |
| 9 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |
| 10 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |
| 11 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |
| 12 | X | X | X | X | X | X | X | X | X | - | X | - | X | X |

APPENDIX D—Continued

| No. | | | | | | Participation Dates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | March | 1 | 2 | 3 | 12 | 14 | 15 | 16 | 17 | 19 | 21 | 22 | 23 | 24 |
| 1 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3 | | X | X | - | - | - | - | - | - | - | - | - | - | - |
| 4 | | X | X | X | - | - | - | - | - | - | - | - | - | - |
| 5 | | X | X | - | - | - | - | - | - | - | - | - | - | - |
| 6 | | - | E | - | X | X | X | X | X | - | - | - | - | - |
| 7 | | - | X | - | X | X | X | M | X | - | - | - | - | - |
| 8 | | - | M | - | X | M | X | X | X | - | - | - | - | - |
| 9 | | - | X | - | X | X | X | X | X | - | - | - | - | - |
| 10 | | - | X | - | X | X | - | X | - | X | X | X | X | M |
| 11 | | - | X | - | X | X | - | X | - | M | X | I | IX | X |
| 12 | | - | X | - | X | X | - | X | - | X | X | X | X | X |

Note. (-) = a nonexercise day. X = participation. S = sick. M = a miss for a reason other than sickness. I = injury. IX = injured but tried to exercise. E = exercised on own.

## Appendix E

RMR Raw Data

# APPENDIX E

## RMR Raw Data

| S1 | Pre test | Min. | 2/21 | 2/22 | 2/23 | 2/24 | Ave. |
|---|---|---|---|---|---|---|---|
| | | | Post-test days | | | | |
| | 258 | 4 | | | | | |
| | 234 | 8 | 424 | 397 | 418 | 382 | 405 |
| | 220 | 12 | 354 | 331 | 362 | 314 | 340 |
| | 248 | 16 | 332 | 298 | 330 | 340 | 325 |
| | 209 | 20 | 319 | 299 | 347 | 338 | 326 |
| | 229 | 24 | 246 | 334 | 291 | 315 | 297 |
| | 230 | 28 | 263 | 334 | 329 | 308 | 309 |
| | 231 | 32 | 266 | 331 | 357 | 323 | 319 |
| | 228 | 36 | 292 | 298 | 327 | 296 | 303 |
| | 224 | 40 | 310 | 278 | 331 | 311 | 308 |
| | 223 | 44 | 235 | 269 | 417 | 271 | 298 |
| | 220 | 48 | 264 | 302 | 324 | 232 | 281 |
| | 212 | 52 | 246 | 365 | 386 | 275 | 318 |
| | 207 | 56 | 265 | 293 | 336 | 337 | 308 |
| | 236 | 60 | 262 | 272 | 303 | 283 | 280 |
| | 231 | 64 | 258 | 298 | 351 | 296 | 301 |
| | 220 | 68 | 242 | 280 | 382 | 347 | 312 |
| | 233 | 72 | 243 | 276 | 339 | 361 | 305 |
| | 222 | 76 | 244 | 317 | 306 | 346 | 303 |
| | 233 | 80 | 240 | 265 | 373 | 338 | 304 |
| | 203 | 84 | 288 | 285 | 290 | 394 | 314 |
| | 229 | 88 | 234 | 315 | 312 | 375 | 309 |
| | 262 | 92 | 235 | 298 | 300 | 309 | 286 |
| | 221 | M RMR | 276 | 306 | 341 | 322 | |
| | 229 | | | | | | |
| | 182 | | | | | | |
| | 237 | M HR | 177 | 178 | 177 | 177 | |
| | 179 | M WL | 138 | 145 | 141 | 150 | |
| | 250 | | | | | | |
| | 152 | | | | | | |
| | 265 | | | | | | |
| | 176 | | | | | | |
| | 273 | | | | | | |
| | 278 | | | | | | |
| | 266 | | | | | | |
| | 7950 | | | | | | |
| | N=35 | | | | | | |
| | M=227 | | | | | | |

Appendix E—Continued

| S2 | Pre test | Min. | Post-test days 2/21 | 2/22 | 2/23 | 2/24 | Ave. |
|---|---|---|---|---|---|---|---|
| | 224 | 4 | | | | | |
| | 218 | 8 | 353 | 417 | 468 | 381 | 404 |
| | 260 | 12 | 333 | 340 | 368 | 308 | 337 |
| | 228 | 16 | 315 | 363 | 364 | 292 | 334 |
| | 241 | 20 | 295 | 329 | 322 | 253 | 300 |
| | 231 | 24 | 288 | 327 | 337 | 242 | 299 |
| | 229 | 28 | 281 | 358 | 326 | 230 | 299 |
| | 224 | 32 | 283 | 329 | 346 | 202 | 290 |
| | 226 | 36 | 275 | 318 | 375 | 218 | 297 |
| | 245 | 40 | 276 | 305 | 354 | 268 | 301 |
| | 241 | 44 | 300 | 311 | 390 | 245 | 312 |
| | 226 | 48 | 298 | 314 | 367 | xxx | 326 |
| | 250 | 52 | 283 | 308 | 335 | 238 | 291 |
| | 229 | 56 | 298 | 298 | 345 | 242 | 296 |
| | 204 | 60 | 303 | 318 | 349 | 245 | 304 |
| | 221 | 64 | 286 | 305 | 359 | 234 | 296 |
| | 224 | 68 | 262 | 302 | 387 | 237 | 297 |
| | 241 | 72 | 272 | 299 | 360 | 233 | 291 |
| | 235 | 76 | 339 | 289 | 372 | 247 | 312 |
| | 220 | 80 | 279 | 293 | 378 | 244 | 299 |
| | 219 | 84 | 275 | 311 | 344 | 232 | 291 |
| | 237 | 88 | 271 | 297 | 335 | 270 | 293 |
| | 221 | 92 | 268 | 299 | 327 | 260 | 289 |
| | 228 | M RMR | 292 | 320 | 359 | 253 | |
| | 227 | | | | | | |
| | 240 | | | | | | |
| | 243 | M HR | 168 | 166 | 168 | 162 | |
| | 249 | M WL | 125 | 118 | 121 | 125 | |
| | 226 | | | | | | |
| | 255 | | | | | | |
| | 243 | | | | | | |
| | 252 | | | | | | |
| | 237 | | | | | | |
| | 224 | | | | | | |
| | 7929 | | | | | | |
| | N=35 | | | | | | |
| | M=227 | | | | | | |

Appendix E—Continued

| S4 | Pre test | Min. | Post-test days 2/28 | 3/1 | 3/2 | Ave. |
|---|---|---|---|---|---|---|
| | 237 | 4 | | | | |
| | 238 | 8 | 328 | 313 | 297 | 313 |
| | 241 | 12 | 278 | 247 | xxx | 263 |
| | 233 | 16 | 278 | 232 | 250 | 253 |
| | 226 | 20 | 226 | 216 | 257 | 233 |
| | 238 | 24 | 241 | 213 | 285 | 246 |
| | 235 | 28 | 232 | 196 | 252 | 227 |
| | 243 | 32 | 228 | 192 | 244 | 221 |
| | 226 | 36 | 226 | 227 | 246 | 233 |
| | 225 | 40 | 225 | 181 | 284 | 230 |
| | 229 | 44 | 250 | 220 | 252 | 241 |
| | 247 | 48 | 268 | 221 | 248 | 246 |
| | 220 | 52 | 240 | 197 | 242 | 226 |
| | 231 | 56 | 254 | 236 | 244 | 245 |
| | 240 | 60 | 243 | 211 | 285 | 246 |
| | 219 | 64 | 254 | 237 | 250 | 247 |
| | 222 | 68 | 273 | 256 | 274 | 267 |
| | 236 | 72 | 277 | 242 | 225 | 248 |
| | 247 | 76 | 238 | 233 | 262 | 244 |
| | 228 | 80 | 275 | 199 | 250 | 241 |
| | 251 | 84 | 274 | xxx | xxx | 274 |
| | 233 | 88 | 286 | xxx | 243 | 265 |
| | 241 | 92 | 250 | xxx | xxx | 250 |
| | 246 | M RMR | 257 | 225 | 257 | |
| | 249 | | | | | |
| | 245 | | | | | |
| | 245 | M HR | 182 | 178 | 178 | |
| | 246 | M WL | 146 | 124 | 125 | |
| | 234 | | | | | |
| | 242 | | | | | |
| | 244 | | | | | |
| | 246 | | | | | |
| | 219 | | | | | |
| | 249 | | | | | |
| | 248 | | | | | |
| | 226 | | | | | |
| | 227 | | | | | |
| | 242 | | | | | |
| | 9472 | | | | | |
| | N=40 | | | | | |
| | M=237 | | | | | |

Appendix E—Continued

| S5 | Pre test | Min. | 2/28 | 3/1 | 3/2 | 3/3 | Ave. |
|---|---|---|---|---|---|---|---|
| | | | | Post-test days | | | |
| | 213 | 4 | | | | | |
| | 223 | 8 | 384 | 281 | 250 | 323 | 310 |
| | 233 | 12 | 305 | 282 | 231 | 266 | 271 |
| | 218 | 16 | 294 | 321 | 228 | 245 | 272 |
| | 221 | 20 | 292 | 277 | 226 | 249 | 261 |
| | 213 | 24 | 284 | xxx | 239 | 246 | 256 |
| | 218 | 28 | 266 | 273 | 249 | 275 | 266 |
| | 219 | 32 | 279 | 271 | 245 | 240 | 259 |
| | 218 | 36 | 284 | 259 | 246 | xxx | 263 |
| | 225 | 40 | 290 | 272 | xxx | 304 | 289 |
| | 246 | 44 | 274 | 252 | 261 | 300 | 272 |
| | 233 | 48 | 299 | 264 | 280 | 296 | 285 |
| | 223 | 52 | 266 | 276 | 306 | 277 | 281 |
| | 258 | 56 | 291 | 253 | 279 | 276 | 275 |
| | 260 | 60 | 288 | 250 | 255 | 244 | 259 |
| | 227 | 64 | 302 | 243 | 257 | 266 | 267 |
| | 241 | 68 | 278 | 273 | 255 | 285 | 273 |
| | 232 | 72 | 315 | 258 | 244 | 239 | 264 |
| | 236 | 76 | 286 | 252 | 266 | 285 | 272 |
| | 243 | 80 | 260 | 264 | 251 | 243 | 255 |
| | 254 | 84 | 270 | 240 | 285 | 236 | 256 |
| | 263 | 88 | 298 | 249 | 262 | 260 | 267 |
| | 241 | 92 | 280 | 253 | xxx | 300 | 278 |
| | 252 | M RMR | 290 | 253 | 256 | 269 | |
| | 266 | | | | | | |
| | 252 | | | | | | |
| | 246 | M HR | 176 | 173 | 179 | 175 | |
| | 248 | M WL | 92 | 90 | 92 | 90 | |
| | 236 | | | | | | |
| | 262 | | | | | | |
| | 264 | | | | | | |
| | 264 | | | | | | |
| | 244 | | | | | | |
| | 249 | | | | | | |
| | 243 | | | | | | |
| | 241 | | | | | | |
| | 242 | | | | | | |
| | 235 | | | | | | |
| | 264 | | | | | | |
| | 9628 | | | | | | |
| | N=40 | | | | | | |
| | M=241 | | | | | | |

Appendix E—Continued

| S6 | Pre test | Min. | 2/28 | Post-test days 3/1 | 3/2 | Ave. |
|---|---|---|---|---|---|---|
| | 207 | 4 | | | | |
| | 183 | 8 | 247 | 268 | 261 | 259 |
| | 172 | 12 | 244 | xxx | 270 | 257 |
| | 174 | 16 | 241 | 267 | 215 | 241 |
| | 176 | 20 | 240 | 247 | 222 | 236 |
| | 154 | 24 | 237 | 257 | 202 | 232 |
| | 183 | 28 | 231 | 250 | 213 | 231 |
| | 189 | 32 | 231 | 196 | 235 | 221 |
| | 206 | 36 | 243 | 227 | 199 | 223 |
| | 173 | 40 | 228 | 226 | 205 | 220 |
| | 260 | 44 | 233 | 197 | 201 | 210 |
| | 254 | 48 | 233 | xxx | 252 | 243 |
| | 242 | 52 | xxx | 270 | 189 | 230 |
| | 249 | 56 | 237 | 243 | 209 | 230 |
| | 245 | 60 | 236 | 226 | 192 | 218 |
| | 237 | 64 | 226 | 234 | 237 | 232 |
| | 245 | 68 | 233 | 205 | 215 | 218 |
| | 243 | 72 | 235 | 200 | 199 | 211 |
| | 220 | 76 | 230 | 213 | 188 | 210 |
| | 224 | 80 | 240 | 194 | 187 | 207 |
| | 222 | 84 | 237 | 224 | 194 | 218 |
| | 221 | 88 | 224 | 236 | 185 | 215 |
| | 234 | M RMR | 224 | 219 | 194 | |
| | 222 | | | | | |
| | 194 | | | | | |
| | 167 | M HR | 161 | 162 | 167 | |
| | 179 | M WL | 74 | 77 | 68 | |
| | 184 | | | | | |
| | 180 | | | | | |
| | 198 | | | | | |
| | 168 | | | | | |
| | 203 | | | | | |
| | 198 | | | | | |
| | 189 | | | | | |
| | 206 | | | | | |
| | 178 | | | | | |
| | 212 | | | | | |
| | 221 | | | | | |
| | 195 | | | | | |
| | 191 | | | | | |
| | 8198 | | | | | |

N=40
M=205

Appendix E—Continued

| S7 | Pre test | Min. | 3/14 | Post-test days 3/15 | 3/16 | 3/17 | Ave. |
|---|---|---|---|---|---|---|---|
| | 295 | 4 | | | | | |
| | 261 | 8 | xxx | xxx | xxx | 490 | 490 |
| | 271 | 12 | xxx | 373 | 310 | 413 | 365 |
| | 250 | 16 | xxx | 366 | 337 | 368 | 357 |
| | 260 | 20 | xxx | 335 | 308 | 344 | 329 |
| | 251 | 24 | xxx | 329 | 287 | 344 | 320 |
| | 270 | 28 | xxx | 330 | 272 | 322 | 308 |
| | 271 | 32 | 352 | 311 | 277 | 313 | 313 |
| | 289 | 36 | 313 | 332 | 264 | 306 | 304 |
| | 280 | 40 | 317 | 354 | 281 | 306 | 315 |
| | 248 | 44 | 303 | 289 | 246 | 333 | 293 |
| | 276 | 48 | 315 | 275 | 306 | 326 | 306 |
| | 261 | 52 | 317 | 316 | 278 | 310 | 305 |
| | 298 | 56 | 315 | 312 | 273 | 323 | 306 |
| | 276 | 60 | 310 | 311 | 264 | 317 | 301 |
| | 303 | 64 | 317 | 307 | 259 | 313 | 299 |
| | 301 | 68 | 309 | 325 | 266 | 301 | 300 |
| | 280 | 72 | 306 | 274 | 257 | 309 | 287 |
| | 251 | 76 | 305 | 272 | 269 | 305 | 288 |
| | 294 | 80 | 295 | xxx | 266 | 300 | 287 |
| | 265 | 84 | 298 | 344 | 264 | 294 | 300 |
| | 276 | 88 | 296 | 294 | 263 | 276 | 282 |
| | 287 | 92 | 292 | 341 | 262 | 297 | 298 |
| | 285 | M RMR | 310 | 320 | 277 | 328 | |
| | 281 | | | | | | |
| | 271 | | | | | | |
| | 260 | M HR | 162 | 163 | 165 | 170 | |
| | 252 | M WL | 177 | 173 | 178 | 190 | |
| | 279 | | | | | | |
| | 238 | | | | | | |
| | 259 | | | | | | |
| | 255 | | | | | | |
| | 249 | | | | | | |
| | 249 | | | | | | |
| | 255 | | | | | | |
| | 258 | | | | | | |
| | 253 | | | | | | |
| | 267 | | | | | | |
| | 261 | | | | | | |
| | 10747 | | | | | | |
| | N=40 | | | | | | |
| | M=269 | | | | | | |

Appendix E—Continued

| S8 | Pre test | Min. | 3/14 | Post-test days 3/15 | 3/17 | Ave. |
|---|---|---|---|---|---|---|
| | 244 | 4 | | | | |
| | 244 | 8 | 358 | xxx | xxx | 358 |
| | 262 | 12 | 280 | 329 | xxx | 304 |
| | 249 | 16 | 278 | 319 | xxx | 299 |
| | 243 | 20 | 302 | 298 | xxx | 300 |
| | 247 | 24 | 310 | 296 | xxx | 303 |
| | 252 | 28 | 299 | 307 | xxx | 303 |
| | 250 | 32 | 291 | 381 | xxx | 336 |
| | 258 | 36 | 298 | 320 | xxx | 309 |
| | 250 | 40 | 308 | 311 | xxx | 310 |
| | 248 | 44 | 314 | 329 | xxx | 322 |
| | 243 | 48 | 306 | 303 | 293 | 301 |
| | 261 | 52 | 334 | 319 | 254 | 302 |
| | 257 | 56 | 313 | 333 | 256 | 301 |
| | 260 | 60 | 301 | 324 | 256 | 294 |
| | 245 | 64 | 280 | 317 | 265 | 287 |
| | 280 | 68 | 285 | 336 | 260 | 327 |
| | 267 | 72 | 328 | 314 | 264 | 302 |
| | 268 | 76 | 310 | 353 | 284 | 316 |
| | 264 | 80 | 310 | 339 | 317 | 322 |
| | 251 | 84 | 323 | xxx | 293 | 308 |
| | 269 | 88 | 301 | xxx | 332 | 346 |
| | 249 | M RMR | 306 | 328 | 281 | |
| | 242 | | | | | |
| | 258 | | | | | |
| | 265 | M HR | 155 | 161 | 169 | |
| | 268 | M WL | 82 | 92 | 92 | |
| | 245 | | | | | |
| | 257 | | | | | |
| | 248 | | | | | |
| | 258 | | | | | |
| | 254 | | | | | |
| | 282 | | | | | |
| | 280 | | | | | |
| | 272 | | | | | |
| | 281 | | | | | |
| | 252 | | | | | |
| | 283 | | | | | |
| | 10338 | | | | | |
| | N=40 | | | | | |
| | M=258 | | | | | |

Appendix E—Continued

| S9 | Pre test | Min. | Post-test days 3/15 | 3/16 | 3/17 | Ave. |
|---|---|---|---|---|---|---|
| | 211 | 4 | | | | |
| | 199 | 8 | 338 | xxx | xxx | 338 |
| | 200 | 12 | 313 | 348 | 270 | 310 |
| | 199 | 16 | 316 | 359 | 283 | 319 |
| | 206 | 20 | 310 | 324 | 269 | 301 |
| | 216 | 24 | 298 | 306 | 295 | 300 |
| | 204 | 28 | 275 | xxx | 290 | 283 |
| | 222 | 32 | 308 | 310 | 304 | 307 |
| | 213 | 36 | 247 | 305 | 289 | 280 |
| | 214 | 40 | 275 | 311 | 295 | 294 |
| | 232 | 44 | 303 | 305 | 285 | 298 |
| | 195 | 48 | 294 | 294 | 291 | 293 |
| | 248 | 52 | 342 | 305 | 285 | 311 |
| | 234 | 56 | xxx | 347 | 271 | 309 |
| | 222 | 60 | 281 | 296 | 259 | 279 |
| | 216 | 64 | 281 | 313 | 270 | 288 |
| | 209 | 68 | 305 | 292 | 316 | 304 |
| | 230 | 72 | 301 | 315 | 270 | 295 |
| | 194 | 76 | 293 | 336 | 263 | 297 |
| | 217 | 80 | 294 | 311 | 296 | 300 |
| | 249 | 84 | 319 | 307 | 295 | 307 |
| | 240 | 88 | 312 | 273 | 315 | 300 |
| | 209 | 92 | 296 | xxx | xxx | 296 |
| | 243 | M RMR | 300 | 314 | 286 | |
| | 261 | | | | | |
| | 251 | | | | | |
| | 265 | M HR | 185 | 175 | 182 | |
| | 253 | M WL | 97 | 99 | 97 | |
| | 259 | | | | | |
| | 263 | | | | | |
| | 262 | | | | | |
| | 248 | | | | | |
| | 248 | | | | | |
| | 234 | | | | | |
| | 218 | | | | | |
| | 215 | | | | | |
| | 199 | | | | | |
| | 244 | | | | | |
| | 225 | | | | | |
| | 256 | | | | | |
| | 9123 | | | | | |
| | N=40 | | | | | |
| | M=228 | | | | | |

Appendix E—Continued

| S10 | Pre test | Min. | 3/15 | Post-test days 3/16 | 3/17 | Ave. |
|---|---|---|---|---|---|---|
| | 180 | 4 | | | | |
| | 183 | 8 | 227 | xxx | 225 | 226 |
| | 187 | 12 | 208 | 196 | 197 | 200 |
| | 176 | 16 | 189 | 212 | 195 | 199 |
| | 175 | 20 | 203 | 198 | 186 | 197 |
| | 176 | 24 | 212 | 206 | 181 | 200 |
| | 207 | 28 | 185 | 196 | 184 | 188 |
| | 204 | 32 | 184 | 209 | 187 | 193 |
| | 202 | 36 | 175 | 209 | 181 | 188 |
| | 202 | 40 | 178 | 207 | 185 | 190 |
| | 211 | 44 | 192 | 168 | 184 | 181 |
| | 201 | 48 | 182 | 184 | 190 | 185 |
| | 202 | 52 | 199 | 225 | 172 | 199 |
| | 200 | 56 | 207 | 223 | 171 | 200 |
| | 208 | 60 | 183 | 218 | 152 | 184 |
| | 199 | 64 | 179 | 212 | 196 | 196 |
| | 202 | 68 | 185 | 206 | 181 | 191 |
| | 200 | 72 | 221 | 198 | 184 | 201 |
| | 210 | 76 | 193 | 214 | 179 | 195 |
| | 188 | 80 | 208 | 203 | 182 | 198 |
| | 204 | 84 | 169 | 199 | 185 | 184 |
| | 208 | 88 | 216 | 203 | 186 | 202 |
| | 209 | 92 | 171 | 199 | xxx | 185 |
| | 212 | M RMR | 194 | 204 | 185 | |
| | 188 | | | | | |
| | 221 | | | | | |
| | 206 | M HR | 171 | 167 | 172 | |
| | 219 | M WL | 94 | 94 | 93 | |
| | 194 | | | | | |
| | 209 | | | | | |
| | 209 | | | | | |
| | 213 | | | | | |
| | 225 | | | | | |
| | 215 | | | | | |
| | 200 | | | | | |
| | 222 | | | | | |
| | 218 | | | | | |
| | 210 | | | | | |
| | 209 | | | | | |
| | 220 | | | | | |
| | 8122 | | | | | |

N=40
M=203

Appendix E—Continued

| S11 | Pre test | Min. | 3/21 | Post-test days 3/22 | 3/23 | Ave. |
|---|---|---|---|---|---|---|
| | 240 | 4 | | | | |
| | 261 | 8 | | | | |
| | 247 | 12 | xxx | 305 | xxx | 305 |
| | 266 | 16 | 310 | 270 | xxx | 290 |
| | 267 | 20 | 270 | 322 | xxx | 296 |
| | 229 | 24 | 299 | 322 | 282 | 301 |
| | 270 | 28 | 274 | 299 | 277 | 283 |
| | 252 | 32 | 256 | 314 | xxx | 285 |
| | 261 | 36 | 294 | 290 | xxx | 292 |
| | 268 | 40 | 264 | 284 | xxx | 274 |
| | 237 | 44 | 304 | 254 | 256 | 271 |
| | 240 | 48 | 268 | 328 | 278 | 291 |
| | 221 | 52 | 313 | 322 | 274 | 303 |
| | 248 | 56 | 215 | 273 | 273 | 254 |
| | 220 | 60 | 290 | xxx | 285 | 288 |
| | 246 | 64 | 228 | 258 | 296 | 261 |
| | 244 | 68 | 247 | 259 | 282 | 263 |
| | 247 | 72 | 211 | 262 | 255 | 243 |
| | 239 | 76 | 246 | 298 | 240 | 261 |
| | 254 | 80 | 260 | 249 | 268 | 259 |
| | 241 | 84 | 275 | 256 | 279 | 270 |
| | 242 | 88 | 325 | 310 | 250 | 295 |
| | 230 | 92 | 323 | xxx | 260 | 292 |
| | 221 | M RMR | 274 | 288 | 270 | |
| | 223 | | | | | |
| | 218 | | | | | |
| | 213 | M HR | 179 | 182 | 181 | |
| | 205 | M WL | 137 | 140 | 137 | |
| | 214 | | | | | |
| | 214 | | | | | |
| | 201 | | | | | |
| | 218 | | | | | |
| | 209 | | | | | |
| | 228 | | | | | |
| | 218 | | | | | |
| | 8032 | | | | | |
| | N=35 | | | | | |
| | M=229 | | | | | |

Appendix E—Continued

| S12 | Pre test | Min. | 3/21 | Post-test days 3/23 | 3/24 | Ave. |
|---|---|---|---|---|---|---|
| | 228 | 4 | | | | |
| | 262 | 8 | | | | |
| | 254 | 12 | | | 285 | 285 |
| | 244 | 16 | 285 | 309 | 250 | 281 |
| | 259 | 20 | 282 | 315 | 230 | 276 |
| | 243 | 24 | 263 | 279 | 225 | 256 |
| | 263 | 28 | 264 | 332 | 210 | 269 |
| | 236 | 32 | 270 | 357 | 216 | 281 |
| | 249 | 36 | 262 | 374 | 214 | 283 |
| | 243 | 40 | 258 | 382 | 217 | 286 |
| | 239 | 44 | 268 | 319 | 221 | 269 |
| | 252 | 48 | 273 | 330 | 219 | 274 |
| | 242 | 52 | 281 | 373 | 247 | 300 |
| | 235 | 56 | 287 | 357 | 241 | 295 |
| | 250 | 60 | 292 | 352 | 221 | 285 |
| | 251 | 64 | 299 | 296 | 209 | 268 |
| | 293 | 68 | 280 | 316 | 213 | 270 |
| | 226 | 72 | 285 | 230 | 209 | 241 |
| | 274 | 76 | 286 | 252 | 213 | 250 |
| | 242 | 80 | xxx | 294 | 210 | 252 |
| | 251 | 84 | 290 | 385 | 208 | 294 |
| | 268 | 88 | 288 | 298 | 199 | 262 |
| | 288 | 92 | 293 | xxx | 200 | 247 |
| | 259 | M RMR | 279 | 324 | 222 | |
| | 264 | | | | | |
| | 250 | | | | | |
| | 211 | M HR | 182 | 171 | 182 | |
| | 195 | M WL | 150 | 136 | 145 | |
| | 213 | | | | | |
| | 196 | | | | | |
| | 216 | | | | | |
| | 218 | | | | | |
| | 184 | | | | | |
| | 195 | | | | | |
| | 279 | | | | | |
| | 190 | | | | | |
| | 210 | | | | | |
| | 196 | | | | | |
| | 206 | | | | | |
| | 196 | | | | | |
| | 9440 | | | | | |

N=40
M=236

Appendix E—Continued

| S13 | Pre test | Min. | 3/21 | Post-test days 3/22 | 3/23 | 3/24 | Ave. |
|---|---|---|---|---|---|---|---|
| | 262 | 4 | | | | | |
| | 245 | 8 | | | | | |
| | 266 | 12 | 328 | 443 | xxx | 428 | 400 |
| | 268 | 16 | 286 | 366 | xxx | 412 | 355 |
| | 249 | 20 | 283 | 371 | 333 | 411 | 350 |
| | 268 | 24 | 277 | 384 | 316 | 367 | 336 |
| | 252 | 28 | 298 | 319 | 360 | 316 | 323 |
| | 271 | 32 | 256 | 323 | 350 | 350 | 320 |
| | 265 | 36 | 287 | 335 | 321 | 327 | 318 |
| | 238 | 40 | 313 | 324 | 295 | 393 | 331 |
| | 264 | 44 | 304 | 325 | 310 | 350 | 322 |
| | 254 | 48 | 281 | 343 | 322 | 317 | 316 |
| | 234 | 52 | 286 | 310 | 363 | 317 | 319 |
| | 272 | 56 | 308 | 366 | 337 | 312 | 331 |
| | 257 | 60 | 339 | 372 | 298 | 316 | 331 |
| | 239 | 64 | 303 | 370 | 294 | 318 | 321 |
| | 241 | 68 | 284 | 329 | 321 | 312 | 312 |
| | 267 | 72 | 328 | 339 | 326 | 348 | 335 |
| | 255 | 76 | 321 | 337 | 344 | 378 | 345 |
| | 255 | 80 | 285 | 319 | 380 | 308 | 323 |
| | 271 | 84 | 297 | 338 | 358 | 307 | 325 |
| | 268 | 88 | 301 | 323 | 305 | 352 | 320 |
| | 237 | 92 | 275 | 326 | 300 | 300 | 354 |
| | 258 | M RMR | 297 | 346 | 328 | 345 | |
| | 262 | | | | | | |
| | 244 | | | | | | |
| | 235 | M HR | 180 | 178 | 180 | 178 | |
| | 236 | M WL | 145 | 151 | 155 | 155 | |
| | 237 | | | | | | |
| | 231 | | | | | | |
| | 232 | | | | | | |
| | 234 | | | | | | |
| | 228 | | | | | | |
| | 230 | | | | | | |
| | 257 | | | | | | |
| | 262 | | | | | | |
| | 261 | | | | | | |
| | 275 | | | | | | |
| | 259 | | | | | | |
| | 253 | | | | | | |
| | 10092 | | | | | | |
| | N=40 | | | | | | |
| | M=252 | | | | | | |

Appendix F

Average Heart Rates and Watts
Measured Every Six Minutes
During Exercise Days

# APPENDIX F

Average Heart Rates and Watts Measured Every Six Minutes During the Exercise Days

| Days | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D1 | 168/105 | 180/103 | 168/94 | 179/83 | 160/56 | 165/137 | 172/75 | 177/80 | 166/69 | 180/105 | 170/98 | 179/114 |
| D2 | 173/112 | 178/106 | 172/108 | 181/82 | 158/62 | 170/148 | 181/89 | 170/84 | XX | 181/108 | 170/113 | 179/120 |
| D3 | 174/117 | 170/112 | 169/107 | 177/80 | 167/65 | 173/154 | 170/85 | 180/88 | 171/68 | 180/113 | 181/119 | 181/120 |
| D4 | 173/131 | 175/120 | 177/127 | 179/87 | 159/62 | 172/160 | 169/88 | 183/88 | 160/75 | 184/117 | 177/122 | 171/122 |
| D5 | 177/138 | 167/125 | 181/127 | 181/87 | 162/72 | 168/161 | 171/91 | 181/96 | 163/76 | 185/123 | 184/123 | 176/120 |
| D6 | 178/145 | 166/118 | 181/140 | 179/88 | 158/74 | 173/165 | 162/88 | XX | 164/80 | 182/127 | 183/131 | 176/130 |
| D7 | 177/141 | 168/121 | XX | 177/88 | XX | 173/169 | 177/89 | 183/89 | 168/83 | 180/129 | 185/145 | 171/131 |
| D8 | 177/150 | 162/125 | 182/146 | 173/90 | 161/74 | 169/165 | XX | 185/94 | 165/82 | 179/130 | 183/139 | 175/129 |
| D9 | | | 178/124 | 176/92 | 162/77 | XX | 172/97 | XX | 176/81 | 178/130 | 181/140 | 176/135 |

APPENDIX F—Continued

| Days | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D10 | | | 178 / 125 | 179 / 92 | 167 / 68 | 168 / 172 | 166 / 95 | 183 / 95 | 170 / 85 | 184 / 130 | 179 / 144 | 177 / 135 |
| D11 | | | XX | 175 / 90 | XX | 162 / 177 | 155 / 82 | XX | 164 / 89 | 178 / 132 | 176 / 148 | 174 / 135 |
| D12 | | | | | | 163 / 173 | 161 / 93 | 185 / 97 | 171 / 94 | 174 / 135 | 173 / 138 | 182 / 141 |
| D13 | | | | | | 165 / 178 | XX | 175 / 99 | 167 / 94 | 180 / 140 | XX | 179 / 145 |
| D14 | | | | | | 170 / 190 | 169 / 92 | 182 / 97 | 172 / 93 | 179 / 137 | 182 / 150 | 180 / 145 |
| D15 | | | | | | | | | | 182 / 140 | XX | 178 / 151 |
| D16 | | | | | | | | | | 181 / 137 | 171 / 136 | 180 / 155 |
| D17 | | | | | | | | | | XX | 182 / 145 | 178 / 155 |

Note. XX indicates an absence. Top number = average heart rate for the day.
Bottom number = average workload for the day.

Appendix G

Table of Cell Means for RMR Values

# APPENDIX G

Table of Cell Means for RMR Values

| Time | Group A | Group B | Group C | Group D | Marginal |
|---|---|---|---|---|---|
| 1 | 227.00 | 227.00 | 239.50 | 239.00 | 234.33 |
| 2 | 404.50 | 294.00 | 353.00 | 370.00 | 351.08 |
| 3 | 338.50 | 263.67 | 294.75 | 330.00 | 303.08 |
| 4 | 329.50 | 255.33 | 293.50 | 308.67 | 293.75 |
| 5 | 313.00 | 243.33 | 281.75 | 307.33 | 283.75 |
| 6 | 298.00 | 244.67 | 280.75 | 297.67 | 278.83 |
| 7 | 304.00 | 241.33 | 270.50 | 291.67 | 274.08 |
| 8 | 304.50 | 233.67 | 287.25 | 295.33 | 278.75 |
| 9 | 300.00 | 239.67 | 270.25 | 297.67 | 274.42 |
| 10 | 304.50 | 246.33 | 277.25 | 297.00 | 279.00 |
| 11 | 305.00 | 241.00 | 273.50 | 287.33 | 274.08 |
| 12 | 303.50 | 258.00 | 271.25 | 293.67 | 278.92 |
| 13 | 304.50 | 245.67 | 279.25 | 307.33 | 282.08 |
| 14 | 302.00 | 250.00 | 279.00 | 293.33 | 279.17 |
| 15 | 292.00 | 241.00 | 264.50 | 301.33 | 272.42 |
| 16 | 298.50 | 248.67 | 267.50 | 283.33 | 271.92 |
| 17 | 304.50 | 252.67 | 280.50 | 281.67 | 277.83 |
| 18 | 298.00 | 241.00 | 271.25 | 273.00 | 268.58 |
| 19 | 307.50 | 242.00 | 274.00 | 285.33 | 274.42 |
| 20 | 301.50 | 234.33 | 276.75 | 278.00 | 270.58 |
| 21 | 302.50 | 249.33 | 274.75 | 296.33 | 278.42 |
| 22 | 301.00 | 249.00 | 271.00 | 292.33 | 275.83 |
| 23 | 287.50 | 248.00 | 281.25 | 297.67 | 278.08 |

Note. Time frame 1 represents baseline values. The other time frames indicate four minute intervals.

## Appendix H

### Multiple Comparison of the Mean RMR Values Across the Time Intervals

# APPENDIX H

Multiple Comparison of the Mean RMR Values Across the Time Intervals

| | Four Minute Time Intervals | | | | | | |
|---|---|---|---|---|---|---|---|
| Time | 1 | 18 | 20 | 16 | 15 | 7 | 11 |
| 1 | - | 34.25* | 36.25* | 37.58* | 28.08* | 39.75* | 39.75* |
| 18 | | - | 2.0 | 3.33 | 5.5 | 5.83 | 5.83 |
| 20 | | | - | 1.33 | 1.83 | 3.50 | 3.50 |
| 16 | | | | - | .5 | 2.17 | 2.17 |
| 15 | | | | | - | 1.67 | 1.67 |
| 7 | | | | | | - | - |
| 11 | | | | | | | - |
| 9 | | | | | | | |
| 19 | | | | | | | |
| 22 | | | | | | | |
| 17 | | | | | | | |
| 23 | | | | | | | |
| 21 | | | | | | | |
| 8 | | | | | | | |
| 6 | | | | | | | |
| 12 | | | | | | | |
| 10 | | | | | | | |
| 14 | | | | | | | |
| 13 | | | | | | | |
| 5 | | | | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | | | | | | | |

APPENDIX H—Continued

| Time | 9 | 19 | Four Minute Time Intervals 22 | 17 | 23 | 21 | 8 |
|---|---|---|---|---|---|---|---|
| 1 | 40.08* | 40.08* | 41.5* | 43.5* | 43.75* | 44.08* | 44.42* |
| 18 | 5.83 | 5.83 | 7.25 | 9.25 | 9.50 | 9.83 | 10.17 |
| 20 | 3.83 | 3.83 | 5.25 | 7.25 | 7.50 | 7.83 | 8.17 |
| 16 | 2.5 | 2.5 | 3.92 | 5.92 | 6.17 | 6.50 | 6.83 |
| 15 | 2.0 | 2.0 | 3.42 | 5.42 | 5.67 | 6.0 | 6.33 |
| 7 | .33 | .33 | 1.75 | 3.75 | 4.0 | 4.33 | 4.67 |
| 11 | .33 | .33 | 1.75 | 3.75 | 4.0 | 4.33 | 4.67 |
| 9 | - | - | 1.42 | 3.42 | 3.67 | 4.0 | 4.33 |
| 19 | | - | 1.42 | 3.42 | 3.67 | 4.0 | 4.33 |
| 22 | | | - | 2.0 | 2.25 | 2.58 | 2.92 |
| 17 | | | | - | .25 | .58 | .92 |
| 23 | | | | | - | .33 | .67 |
| 21 | | | | | | - | .33 |
| 8 | | | | | | | - |
| 6 | | | | | | | |
| 12 | | | | | | | |
| 10 | | | | | | | |
| 14 | | | | | | | |
| 13 | | | | | | | |
| 5 | | | | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | | | | | | | |

APPENDIX H—Continued

| Time | | | Four Minute Time Intervals | | | | |
|---|---|---|---|---|---|---|---|
| | 6 | 12 | 10 | 14 | 13 | 5 | 4 |
| 1 | 44.5* | 44.58* | 44.67* | 44.83* | 47.45* | 49.42* | 59.42* |
| 18 | 10.25 | 10.33 | 10.42 | 10.58 | 13.5 | 15.17 | 25.17* |
| 20 | 8.25 | 8.33 | 8.42 | 8.58 | 11.5 | 13.17 | 23.17 |
| 16 | 6.92 | 7.0 | 7.08 | 7.25 | 10.17 | 11.83 | 21.83 |
| 15 | 6.42 | 6.5 | 6.58 | 6.75 | 9.67 | 11.33 | 21.33 |
| 7 | 4.75 | 4.83 | 4.92 | 5.08 | 8.0 | 9.67 | 19.67 |
| 11 | 4.75 | 4.83 | 4.92 | 5.08 | 8.0 | 9.67 | 19.67 |
| 9 | 4.42 | 4.5 | 4.58 | 4.75 | 7.67 | 9.33 | 19.33 |
| 19 | 4.42 | 4.5 | 4.58 | 4.75 | 7.67 | 9.33 | 19.33 |
| 22 | 3.0 | 3.08 | 3.17 | 3.33 | 6.25 | 7.92 | 17.92 |
| 17 | 1.0 | 1.08 | 1.17 | 1.33 | 4.25 | 5.92 | 15.92 |
| 23 | .75 | .83 | .92 | 1.08 | 4.0 | 5.67 | 15.67 |
| 21 | .42 | .5 | .58 | .75 | 3.67 | 5.33 | 15.33 |
| 8 | .08 | .17 | .25 | .42 | 3.33 | 5.0 | 15.0 |
| 6 | - | .08 | .17 | .33 | 3.25 | 4.92 | 14.92 |
| 12 | | - | .08 | .25 | 3.17 | 4.83 | 14.83 |
| 10 | | | - | .17 | 3.08 | 4.75 | 17.75 |
| 14 | | | | - | 2.92 | 4.58 | 14.58 |
| 13 | | | | | - | 1.67 | 11.67 |
| 5 | | | | | | - | 10.00 |
| 4 | | | | | | | - |
| 3 | | | | | | | |
| 2 | | | | | | | |

APPENDIX H—Continued

| Time | Four Minute Time Intervals 3 | 2 |
|---|---|---|
| 1 | 68.75* | 116.75* |
| 18 | 34.5* | 82.5* |
| 20 | 32.5* | 80.5* |
| 16 | 31.17* | 79.17* |
| 15 | 30.67* | 78.67* |
| 7 | 29.0* | 77.0* |
| 11 | 29.0* | 77.0* |
| 9 | 28.67* | 76.67* |
| 19 | 28.67* | 76.67* |
| 22 | 27.25* | 75.25* |
| 17 | 25.25* | 73.25* |
| 23 | 25.0* | 73.0* |
| 21 | 24.67* | 72.67* |
| 8 | 24.33 | 72.33* |
| 6 | 24.25 | 72.25* |
| 12 | 24.17 | 72.17* |
| 10 | 24.08 | 72.08* |
| 14 | 23.92 | 71.92* |
| 13 | 21.0 | 69.0* |
| 5 | 19.33 | 67.33* |
| 4 | 9.33 | 57.33* |
| 3 | - | 48.0* |
| 2 | | - |

*$q(22, 176) = 1.66$, $p < .05$
Note. Time interval one represents the RMR.

Appendix I

Descriptive Data of the Mean RMR Values
Across the Post-test Days

APPENDIX I

Mean Resting Metabolic Rates Across the Post-test Days

| | Days d1 | d2 | d3 | d4 | Average |
|---|---|---|---|---|---|
| S1 | 276 | 306 | 341 | 322 | 311.25 |
| S2 | 292 | 320 | 359 | 253 | 306 |
| S3 | 257 | 225 | 257 | 246 | 246.25 |
| S4 | 290 | 253 | 256 | 269 | 267 |
| S5 | 224 | 219 | 194 | 212 | 212.25 |
| S6 | 310 | 320 | 277 | 328 | 308.75 |
| S7 | 306 | 328 | 281 | 305 | 305 |
| S8 | 300 | 314 | 286 | 300 | 300 |
| S9 | 194 | 204 | 185 | 194 | 194.25 |
| S10 | 274 | 288 | 270 | 277 | 277.25 |
| S11 | 279 | 324 | 222 | 275 | 275 |
| S12 | 297 | 346 | 328 | 345 | 329 |

Appendix J

Multiple Comparison of the RMR Values Across Subjects

# APPENDIX J

Multiple Comparison of RMR Values Across Subjects

| | | Subjects | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 9 | 5 | 3 | 4 | 11 | 10 | 8 |
| | 9 | - | 18.0 | 52.0* | 72.75* | 80.75* | 83.0* | 105.75* |
| | 5 | | - | 33.75 | 54.75* | 62.75* | 65.0* | 87.75* |
| S | 3 | | | - | 20.75 | 28.75 | 31.0 | 53.75* |
| U | 4 | | | | - | 8.0 | 10.25 | 33.0 |
| B | 11 | | | | | - | 2.25 | 25.0 |
| J | 10 | | | | | | - | 22.75 |
| E | 8 | | | | | | | - |
| C | 7 | | | | | | | |
| T | 2 | | | | | | | |
| S | 6 | | | | | | | |
| | 1 | | | | | | | |
| | 12 | | | | | | | |

APPENDIX J—Continued

| | | Subjects 7 | 2 | 6 | 1 | 12 |
|---|---|---|---|---|---|---|
| | 9 | 110.75* | 111.75* | 114.50* | 117.0* | 134.75* |
| | 5 | 92.75* | 93.75* | 96.5* | 99.0* | 116.75* |
| S | 3 | 58.75* | 59.75* | 62.5* | 65.0* | 82.75* |
| U | 4 | 38.0* | 39.0* | 41.75* | 44.25* | 62.0* |
| B | 11 | 30.0 | 31.0 | 33.75 | 36.25* | 54.0* |
| J | 10 | 27.75 | 28.75 | 31.5 | 34.0 | 51.75* |
| E | 8 | 5.0 | 6.0 | 8.75 | 11.25 | 29.0 |
| C | 7 | - | 1.0 | 3.75 | 6.25 | 24.0 |
| T | 2 | | - | 2.75 | 5.25 | 23.0 |
| S | 6 | | | - | 2.5 | 20.25 |
| | 1 | | | | - | 17.75 |
| | 12 | | | | | - |

*$q(12, 33) = 5.00$, $p < .05$

## Appendix K

Descriptive Data of the Mean Exercise Heart Rate Values
Across the Post-test Days

# APPENDIX K

The Mean Exercise Heart Rate Values Across the Post-test Days

| | Days | | | | |
|---|---|---|---|---|---|
| | d1 | d2 | d3 | d4 | Average |
| S1 | 177 | 178 | 177 | 177 | 177.25 |
| S2 | 168 | 166 | 168 | 162 | 166 |
| S3 | 182 | 178 | 178 | 179 | 179.25 |
| S4 | 176 | 173 | 179 | 175 | 175.75 |
| S5 | 161 | 162 | 167 | 163 | 163.25 |
| S6 | 162 | 163 | 165 | 170 | 165 |
| S7 | 155 | 161 | 169 | 162 | 161.75 |
| S8 | 185 | 175 | 182 | 181 | 180.75 |
| S9 | 171 | 167 | 172 | 170 | 170 |
| S10 | 179 | 182 | 181 | 181 | 180.75 |
| S11 | 182 | 171 | 182 | 178 | 178.25 |
| S12 | 180 | 178 | 180 | 178 | 179 |

Appendix L

Multiple Comparison of the Mean Exercise Heart
Rate Values Across Subjects

# APPENDIX L

Multiple Comparison of the Mean Exercise Heart Rate Values Across Subjects

| | | Subjects | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 7 | 5 | 6 | 2 | 9 | 4 | 1 |
| | 7 | - | 1.5 | 3.25 | 4.25* | 8.25* | 14.0* | 15.5* |
| | 5 | | - | 1.75 | 2.75 | 6.75* | 12.5* | 14.0* |
| S | 6 | | | - | 1.0 | 5.0* | 10.75* | 12.25* |
| U | 2 | | | | - | 4.0 | 9.75* | 11.25* |
| B | 9 | | | | | - | 5.75* | 7.25* |
| J | 4 | | | | | | - | 1.5 |
| E | 1 | | | | | | | - |
| C | 11 | | | | | | | |
| T | 12 | | | | | | | |
| S | 3 | | | | | | | |
| | 8 | | | | | | | |
| | 10 | | | | | | | |

APPENDIX L—Continued

| | | Subjects 11 | 12 | 3 | 8 | 10 |
|---|---|---|---|---|---|---|
| | 7 | 16.5* | 17.25* | 7.5* | 19.0* | 19.0* |
| | 5 | 15.0* | 15.75* | 16.0* | 17.5* | 17.5* |
| S | 6 | 13.25* | 14.0* | 14.25* | 15.75* | 15.75* |
| U | 2 | 12.25* | 13.0* | 13.25* | 14.75* | 14.75* |
| B | 9 | 8.25* | 9.0* | 9.25* | 10.75* | 10.75* |
| J | 4 | 2.5 | 3.25 | 3.5 | 5.0* | 5.0* |
| E | 1 | 1.0 | 1.75 | 2.0 | 3.5 | 3.5 |
| C | 11 | - | .75 | 1.0 | 2.5 | 2.5 |
| T | 12 | | - | .25 | 1.75 | 1.75 |
| S | 3 | | | - | 1.5 | 1.5 |
| | 8 | | | | - | - |
| | 10 | | | | | - |

*$q(12, 33) = 5.00$, $p < .05$

## Appendix M

### Descriptive Data of the Mean Percent Heart Rate Reserve Values Utilized Across the Post-test Days

## APPENDIX M

The Mean Percent Heart Rate Reserve Values
Utilized Across the Post-test Days

| | Days | | | | |
|---|---|---|---|---|---|
| | d1 | d2 | d3 | d4 | Average |
| S1 | 82.58 | 83.33 | 82.58 | 82.58 | 82.77 |
| S2 | 74.42 | 72.87 | 74.42 | 69.76 | 72.87 |
| S3 | 86.15 | 83.08 | 83.08 | 83.85 | 84.04 |
| S4 | 80.62 | 78.29 | 82.95 | 79.84 | 80.43 |
| S5 | 67.97 | 68.75 | 72.66 | 69.53 | 69.73 |
| S6 | 71.43 | 72.18 | 73.68 | 77.44 | 73.68 |
| S7 | 64.52 | 64.35 | 75.81 | 70.16 | 69.96 |
| S8 | 87.50 | 79.17 | 85.00 | 84.17 | 83.96 |
| S9 | 77.37 | 74.45 | 78.10 | 76.64 | 76.64 |
| S10 | 82.58 | 84.85 | 84.09 | 84.09 | 83.90 |
| S11 | 86.05 | 77.52 | 86.05 | 82.95 | 83.14 |
| S12 | 83.72 | 82.17 | 83.72 | 82.17 | 82.95 |

Appendix N

Multiple Comparison of the Mean Heart Rate Reserve
Values Across Subjects

# APPENDIX N

## Multiple Comparison of the Mean Percent Heart Rate Reserve Values Across Subjects

| | | Subjects | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 5 | 7 | 2 | 6 | 9 | 4 | 1 |
| | 5 | - | .23 | 3.14 | 3.95* | 6.91* | 10.7* | 13.04* |
| | 7 | | - | 2.91 | 3.72* | 6.68* | 10.47* | 12.81* |
| S | 2 | | | - | .81 | 3.77* | 7.56* | 9.9* |
| U | 6 | | | | - | 2.96 | 6.75* | 9.09* |
| B | 9 | | | | | - | 3.79* | 6.13* |
| J | 4 | | | | | | - | 2.34 |
| E | 1 | | | | | | | - |
| C | 12 | | | | | | | |
| T | 11 | | | | | | | |
| S | 10 | | | | | | | |
| | 8 | | | | | | | |
| | 3 | | | | | | | |

APPENDIX N—Continued

| | | Subjects | | | | |
|---|---|---|---|---|---|---|
| | | 12 | 11 | 10 | 8 | 3 |
| | 5 | 13.22* | 13.41* | 14.17* | 14.23 | 14.31* |
| | 7 | 12.99* | 13.18* | 13.94* | 14.0* | 14.08* |
| S | 2 | 10.08* | 10.27* | 11.03* | 11.09* | 11.17* |
| U | 6 | 9.27* | 9.46* | 10.22* | 10.28* | 10.36* |
| B | 9 | 6.31* | 6.76* | 7.26* | 7.32* | 7.4* |
| J | 4 | 2.52 | 2.71 | 3.47* | 3.53* | 3.61* |
| E | 1 | .18 | .37 | 1.13 | 1.19 | 1.27 |
| C | 12 | - | .19 | .95 | 1.01 | 1.09 |
| T | 11 | | - | .76 | .82 | .9 |
| S | 10 | | | - | .06 | .14 |
| | 8 | | | | - | .08 |
| | 3 | | | | | - |

*$q(12, 33) = 5.00$, $p < .05$

Appendix O

Descriptive Data of the Mean Workload Values Across the Post-test Days

# APPENDIX O

The Mean Workload Values Across the Post-test Days

| | Days d1 | d2 | d3 | d4 | Average |
|---|---|---|---|---|---|
| S1 | 138 | 145 | 141 | 150 | 143.5 |
| S2 | 125 | 118 | 121 | 125 | 122.25 |
| S3 | 146 | 124 | 125 | 132 | 131.75 |
| S4 | 92 | 90 | 92 | 90 | 91 |
| S5 | 74 | 77 | 68 | 73 | 73 |
| S6 | 177 | 173 | 178 | 190 | 179.5 |
| S7 | 82 | 92 | 92 | 89 | 88.75 |
| S8 | 97 | 99 | 97 | 98 | 97.75 |
| S9 | 94 | 94 | 93 | 94 | 93.75 |
| S10 | 137 | 140 | 137 | 138 | 138 |
| S11 | 150 | 136 | 145 | 144 | 143.75 |
| S12 | 145 | 151 | 155 | 155 | 151.5 |

Appendix P

Multiple Comparison of the Average Workload Values Across Subjects

# APPENDIX P

## Multiple Comparison of the Average Workload Values Across Subjects

| | | Subjects 5 | 7 | 4 | 9 | 8 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|
| | 5 | - | 15.75* | 18.0* | 20.75* | 24.75* | 49.25* | 58.75* |
| | 7 | | - | 2.25 | 5.0 | 9.0* | 33.5* | 43.0* |
| S | 4 | | | - | 2.75 | 6.75 | 31.25* | 40.75* |
| U | 9 | | | | - | 4.0 | 28.5* | 38.0* |
| B | 8 | | | | | - | 24.5* | 34.0* |
| J | 2 | | | | | | - | 9.5* |
| E | 3 | | | | | | | - |
| C | 10 | | | | | | | |
| T | 1 | | | | | | | |
| S | 11 | | | | | | | |
| | 12 | | | | | | | |
| | 6 | | | | | | | |

APPENDIX P—Continued

| | | Subjects 10 | 1 | 11 | 12 | 6 |
|---|---|---|---|---|---|---|
| | 5 | 65.0* | 70.5* | 70.75* | 78.5* | 106.5* |
| | 7 | 49.25* | 54.75* | 55.0* | 62.75* | 91.0* |
| S | 4 | 47.0* | 52.5* | 52.75* | 60.5* | 88.5* |
| U | 9 | 44.25* | 49.75* | 50.0* | 57.75* | 85.75* |
| B | 8 | 40.25* | 45.75* | 46.0* | 53.75* | 81.75* |
| J | 2 | 15.75* | 21.25* | 21.5* | 29.25* | 57.25* |
| E | 3 | 6.25 | 11.75* | 12.0* | 19.75* | 47.75* |
| C | 10 | - | 5.5 | 5.75 | 13.5* | 41.5* |
| T | 1 | | - | .25 | 8.0* | 36.0* |
| S | 11 | | | - | 7.75* | 35.75* |
| | 12 | | | | - | 28.0* |
| | 6 | | | | | - |

*$q(12, 33) = 5.00$, $p < .05$

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