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The cardiovascular and metabolic adaptations to iso-caloric moderate intensity and high intensity exercise

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The Cardiovascular and Metabolic Adaptations to Iso-caloric Moderate Intensity and High Intensity Exercise

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CHAPTER I

INTRODUCTION

Cardiovascular disease is the leading cause of death in the industrialized nations, and accounts for 1 million deaths in the United States each year (McArdle, Katch & Katch, 1991). One of the major risk factors for cardiovascular disease is physical inactivity, which is a behavioral modified risk factor. Physical inactivity plagues 59% of the people in the United States (ACSM Resource Manual, 1998). Physical inactivity often leads to obesity, diabetes, hypertension and hypercholemia, and places sedentary individuals at more risk for cardiovascular disease (CVD), or coronary heart disease (CHD). The question which remains unclear is the quantity and quality of physical activity needed to acquire a health related quality of life and physical fitness.

Exercise and/or physical activity has been divided into two categories, depending on the goal of the individual. The quality of **leisure time physical activity** is most often assessed by energy expenditure, where as the second category, **cardiorespiratory fitness**, is measured by the cardiovascular and metabolic adaptations to the intensity, frequency and duration of the exercise. Both leisure time physical activity and cardiorespiratory fitness are inversely related to CHD (Berlin & Colditz, 1990; Powell, Thompson, Caspersen & Kendrick, 1987). Leisure time physical activity may reduce the chance for chronic disease and improve metabolic function; nonetheless, it may not improve cardiovascular fitness. It is important to note that cardiorespiratory fit men, in a study by Hein, Suadicani and Gumtelberg (1992), had a 67% and 78% lower risk of all-cause and cardiovascular disease mortality in comparison to the unfit.

The American College of Sports Medicine recommends the quantity and quality of exercise for developing and maintaining cardiorespiratory fitness in healthy adults (Pollock et al., 1998). It recommends that healthy adults exercise 3-5 days per week, 20-60 minutes of continuous or intermittent aerobic activity, at an intensity of 65%-85% of the maximal heart rate reserve (HRR) (Pollock et al. 1998).

Reducing the risk of cardiovascular disease is not the only benefit of physical activity. According to ACSM, exercise promotes an increase of lean body mass, an increase in maximal oxygen consumption, a deferred lactate accumulation, and an increase in stroke volume and cardiac output. Controversy about the quality and quantity of exercise still hinders the development of a precise prescription in order to improve the cardiovascular and metabolic systems.

Statement of the Problem

Five components are considered when developing guidelines for exercise prescriptions: frequency, intensity, duration, mode and progression. As recommended by ACSM, exercising 3-5 days per week is sufficient; however, intensity and duration are the subject of much more debate. Duration is dependent on the intensity of the activity (Pollock et al., 1998). A low or moderate intensity exercise session should be of longer duration to get the cardiorespiratory benefit. Consequently, this is recommended for the non-competitor due to the attainment of "total fitness", and less risk for injury (Pollock et al., 1998). On the other hand, because of the long duration, this type of workout does not easily fit into the busy lifestyle of the western world. Also, it is increasingly difficult to find large blocks of time to workout according to traditional exercise prescriptions. That is, at 70% of maximal heart rate, a twenty-one year old, apparently healthy person, would have an exercise heart rate prescription of 157 beats/minute. If his maximal oxygen consumption is 50 ml/kg/min, then he will be working at approximately 35ml/kg/min. Provided that this person weighs 70 kilograms, he would be expending 12 kcal/min and require 25 minutes to expend 300 kilocalories. A person must be relatively fit to sustain this exercise prescription since most unfit people can only sustain an exercise intensity of five to seven kcal/min, at which it would take 50 minutes to expend 300 kilocalories. Therefore, the purpose of this study is to test and compare the metabolic and cardiovascular adaptations to isocaloric high- intensity and moderate-intensity exercise. Physical inactivity afflicts 59% of the population of the United States where lack of time remains a highly accepted excuse (ACSM Resource Manual, 1998). Additionally, whether exercise is performed at a high-intensity/long duration or moderate-intensity/short duration, the total volume of training (expressed in kilocalories) is important for fitness improvement. Thus, the resulting improvements will be comparable if the high intensity/short duration and moderate intensity/long duration workouts are isocaloric.

Purpose Statement

Because of the lack of evidence that high-intensity/short duration exercise bouts are more or less beneficial to compared moderate-intensity/long duration exercise, more research is needed to refine a precise prescription. If the physiological adaptations to both workouts are similar, the individual and/or clinician has the option to prescribe an exercise program which fits a busy lifestyle, while still improving cardiorespiratory fitness and decreasing the risk for cardiovascular disease and many other chronic illnesses.

Two exercise programs were developed and were implemented to two separate groups of college-aged females. One program was performed at a high intensity (85% VO_{2max}), while the other program was moderate intensity (60% VO_{2max}). Duration of each exercise will differ; however, the caloric expenditure will be equivalent to 300 kilocalories/workout for both groups. Metabolic adaptations were compared between the pre and post tests, including the maximal oxygen consumption (VO_{2max}), the percent of VO_{2max} at which the ventilatory threshold occurs, the workload (% grade of treadmill), and the relationship between the heart rate (HR) and the oxygen consumption (VO_2), during the entire incremental exercise test. The cardiovascular adaptations, computed as indices from the O_2 pulse, will reflect changes in stroke volume and cardiac output.

As cardiorespiratory fitness improves, so does the ability of the individual to exercise at a higher intensity, thus the total amount of work may increase. By increasing the amount of work performed, more kilocalories are expended, promoting loss of fat mass. Consequently, not only is cardiorespiratory fitness improved, but so is body composition. With enhanced fitness components such as these, the risk of obesity, hypertension, hypercholemia and diabetes are decreased, and may reduce CHD risk by 60% to 70% and increase longevity (Lakka, et al., 1994; Lee, Hsieh, Paffenbarger, 1995; Morris & Froelicher, 1990 and Blair, 1990).

The purpose of this study is to investigate the differences in metabolic and cardiovascular responses to moderate and high intensity training.

Null Hypothesis

The null hypothesis for this study maintains that there will be no difference in cardiovascular and metabolic adaptations between high-intensity and moderate-intensity exercise.

The second hypothesis is that there will be no difference in the cardiovascular and metabolic adaptations before and after high and moderate intensity training, within each treatment group.

BASIC ASSUMPTIONS

1. The subjects participating in this study were sedentary for at least two months prior to exercise testing.
2. All subjects exercised at the prescribed levels during all training sessions.
3. Subjects did not participate in any other exercise program during the six-week treatment.
4. Subjects did not manipulate their diet to promote weight gain or weight loss.
5. Subjects consumed no form of supplementation during the six-week treatment.

CHAPTER II

REVIEW OF LITERATURE

Benefits of Exercise

Aerobic exercise provides numerous benefits to the physiological and psychological aspects of life. Morris and Froelicher (1991) found that regular aerobic physical activity increases aerobic fitness and contributes significantly to the primary and secondary prevention of cardiovascular disease. The American Heart Association (Fletcher et al., 1992) provided a "Statement on Exercise," which summarized the benefits to exercise training. The increase in cardiovascular functional capacity and decreased myocardial oxygen demand in apparently healthy persons, as described by the American College of Sports Medicine (ACSM, 1995), as well as in most cardiovascular disease patients, can be accomplished by exercise training (Fletcher et al., 1992). Pate et al. (1995) stated the benefits in the Journal of the American Medical Association as "A Recommendation from the Center for Disease Control and Prevention and the American College of Sports Medicine." Benefits include decreased fatigue in daily activities, improved sport performance, decreased risk of coronary artery disease, colon and breast cancer, osteoporosis, hypertension, and an improved lipid profile, body composition, and immune function. Although there is little research for the psychological benefits of aerobic exercise, Fletcher et al. (1992) acknowledged a study done by Folkins and Sime (1981) stating aerobic exercise reduces anxiety and depression and provides an enhanced sense of well being. Interestingly, Lee, Hsieh, and Paffenbarger of the Harvard Alumni Study in 1995 indicated that vigorous regular aerobic exercise has greatest effect on longevity. During a 20 year study period, men who expended 1,500 kcal or more weekly in vigorous activity had a 25% lower death rate than their sedentary counterparts. Also, Paffenbarger, Hyde, Wing, and Hsieh (1986) provided research that showed a direct and linear relationship between miles walked per week and reduction in death rate. The more mileage covered while expending 100 kilocalories per mile, the greater the reduction in death.

Relationship of Intensity and Exercise

McArdle, Katch, and Katch (1996) have clearly defined exercise as any and all activity involving work, where work is the combination of force and distance, which disturbs the state of homeostasis. They also indicate that intensity is the specific level at which exercise is maintained, when considering power (energy expenditure or work performed per unit of time), isometric force sustained, or velocity of progression. Exercise intensity affects the physiological adaptations in both the cardiovascular and metabolic systems. Speed (mph), grade (%), distance, or frequency can manipulate the intensity of an endurance exercise.

The newly released exercise standards by the American College of Sports Medicine (1998) state that, in order to develop and maintain cardiorespiratory fitness, exercise intensity must target the range between 65% to 90% of the maximum heart rate (HR_{max}), or 50% to 85% of maximum oxygen uptake reserve ($VO_{2max}R$), which is equivalent to HR reserve (HRR). Intensity is expressed in various ways. Since 1957, exercise intensity has often been prescribed as %HRR because of a study done by Karvonen, Kentala, & Mustala (1957). This was assumed by many exercise specialists such as ACSM (1995), to be directly related to $\%VO_{2max}$. However, Swain and Leutholtz (1997) concluded that %HRR does not correspond to equivalent values of $\%VO_{2max}$ during cycling exercises; rather %HRR was of much closer relationship with $\%VO_2R$. Swain, Leutholtz, King, Haas and Branch (1998) furthered the study by using treadmills as the mode of testing. Conclusions were the same as the cycling mode of testing, where the regressions between %HRR and $\%VO_{2max}$ differed significantly; thus, %HHR was significantly closer to $\%VO_2R$. Though %HRR and $\%VO_2R$ are most similar, all methods of intensity prescription are accurate and reliable. Therefore, it is the investigator's decision of the chosen method. This study prescribes intensity by $\%VO_{2max}$.

Cardiovascular Adaptations to High Intensity and Moderate Intensity Exercise

Stroke Volume

Stroke volume is defined as the quantity of blood ejected with each stroke or heartbeat (McArdle et al., 1996). Stroke volume is determined by an enhanced diastolic filling combined with the force of the myocardial contraction. The heart rate and the venous return influence the diastolic filling. McArdle et al. (1996) explain that an increase in venous return and increased diastolic filling will cause a powerful ejection fraction due to the stretched myocardial fibers and increase contractility. Otto Frank (1895) and E. H. Starling (1915) described the relationship between the force of the contraction as a result of a stretched myocardium, which is now termed as Starling's law of the heart (McArdle et al., 1996).

A resting stroke volume for the average sedentary person is 71 mL. As individuals increase in fitness, the stroke volume increases. Michael Cox (1991) states that the body adapts and improves with endurance training, and increasing stroke volume is one important physiological adaptation. These changes are not limited to just the apparently healthy adults. They also occur in the young, old, and sick. James Hagberg of the Center on Aging (1991) studied high-intensity exercise training in patients with coronary artery disease (CAD). The patients with CAD improved left ventricular function after a four-month high-intensity exercise program, which resulted in an improved stroke volume. Hagberg, Ehsani and Holloszy (1983) showed that an increase in stroke volume is also evident among CAD patients exercising at moderate intensities. In another study by Makrides, Heigenhauser, and Jones (1990), stroke volume increased significantly in sixty and seventy year old men ($p<0.05$) after twelve weeks of high-intensity endurance training. The increased stroke volume in the sixty and seventy year old men was a contributing factor to the fall in submaximal heart rates. Rodeheffer, Gerstenblith, Becker, Fleg, Weisfeldt, and Lakatta (1984), and Gerstenblith, Renlund and Lakatta (1987) related the decrease in the submaximal heart rate to the increased diastolic filling, thus increasing stroke volume. This is recognized as the Frank-Starling mechanism. Ehsani, Ogawa, Miller, Spina, and Jilka (1991) studied cardiovascular adaptations in older men and found an improved left ventricular systolic function, meaning an increase in resting end diastolic volume ($\underline{p} < 0.05$), and a significantly improved stroke volume

($p < 0.05$). High intensity training was the treatment of this study, which subjects performed at 60-70% VO_{2max}, and increased to 70-80% VO_{2max}. Interval training was incorporated two to three times per week, requiring 90-100% of VO_{2max} effort. In 1992, Posner, et al. studied low to moderate intensity endurance training in healthy older men and women. The intensity used in this study (70% of VO2max or approximately 45% of HRR) was not intense enough to significantly decrease resting heart rate, which is indirectly related to stroke volume. It is obvious that stroke volume is highly affected by intense and prolonged training. Coyle, Martin, III, Sinacore, Joyner, Hagberg, and Holloszy (1984) expressed a significant finding that trained individuals have a 120% higher stroke volume than their sedentary counterparts. However, stroke volume is quickly decreased as a result of detraining. Coyle, Martin, III, Bloomfield, Lowry, and Holloszki (1985) studied the effects of three months of detraining and found a 101% lower stroke volume in the detrained when compared to the trained. The increased stroke volume obtained by high intensity and moderate intensity exercise allows the conditioned individual to exercise at similar absolute and relative workloads at a lower heart rate, thus decreasing the myocardial oxygen demand (Levine, Lane, Bucky, Friedman, & Blomqvist 1991).

Stroke Volume and Cardiac Output

Cardiac output refers to the amount of blood pumped by the heart in one minute (McArdle et al., 1996). Both heart rate and stroke volume affect the cardiac output (Cardiac output = Heart rate X Stroke volume). Cardiac output during rest does not significantly vary between a trained and untrained individual. An average cardiac output is 5 L/min. The variance comes with the heart rate and stroke volume. As the heart becomes stronger, as it does with endurance training, the stroke volume is increased. Therefore, at rest the heart rate is much slower in the trained persons to meet the 5 L/min cardiac output, which is needed to meet the demands of the physiological system.

During exercise, cardiac output is different between physically fit individuals and those who are sedentary. Cox (1991) reviewed the cardiorespiratory adaptations to endurance exercise and found a significant increase in maximal exercise cardiac output between the sedentary and active individuals. McArdle et al. (1996) related the increased cardiac output in endurance athletes to heart rate and stroke volume. Trained individuals may have a lower maximum heart rate, but continue to have a higher exercise cardiac output than their sedentary counterparts. Consequently, the great maximal cardiac output of the endurance athlete is due to a large stroke volume. Coyle, Hemmert, and Coggan (1986) observed the detraining effects in cardiac output. Detraining caused a decrease in stroke volume, resulting in an increase in heart rate to maintain the same level of exercise before the detraining period.

Makrides, Heigenhouser, and Jones (1990) observed a significantly increased cardiac output in twenty to thirty year old men and sixty to seventy year old men, after twelve weeks of high intensity endurance training. All subjects were apparently healthy. However, the reasons for the cardiac output increases differed between the young and old. The increased cardiac output was associated with a significant increase in stroke volume, where there was no marked increase in stroke volume in the younger group. However, the increased cardiac output in the younger group was a result of an equal contribution by stroke volume and heart rate. A study conducting a short-term three-day training program where college-aged male subjects exercised two hours each day at moderate intensity indicated an early cardiac output adaptation to exercise (Green, Jones, & Painter, 1990). Cardiac output significantly increased after training due to a higher stroke volume and decreased heart rate. Cardiac output is increased primarily due to increased stroke volume after aerobic training (Astrand, & Rodahl, 1986). Stroke volume is highly effected by the intensity of exercise, when stress is put on the physiological system. Therefore, cardiac output is dependent on the intensity of exercise training.

Metabolic Adaptations to High Intensity and Moderate Intensity Exercise

Oxygen Consumption

The American College of Sports Medicine (1978) and M. L. Pollock (1973) indicate that the improvement in aerobic capacity is directly related to the intensity, duration, and frequency of training. The ACSM has released the statement on the recommendations to improve aerobic capacity, better known as VO_{2max} (1998). Gaesser and Rich (1984) studied the effects of high- and low-intensity exercise on aerobic capacity in twenty to thirty year old men. They hypothesized that minimal effects would result from low intensity training, while the high intensity would have a significant increase in VO_{2max}. However, they observed a significant increase of VO_{2max} in both groups, yet the between groups statistic showed insignificance ($p > .05$). In 1985, Bhambhani and Singh researched the effects of three training intensities, which were low, moderate, and high, on VO_{2max}. The researchers concluded that each training intensity significantly improved VO_{2max}, however the increases were nearly equal showing now significant difference between groups. Eddy, Sparks, and Adelizi (1976) also researched the effects of moderate intensity and high intensity exercise on VO_{2max}, and they too observed no difference between groups exercising at different intensities. Belman and Gaessar (1991) observed no difference in VO_{2max} between high-intensity and low-intensity training after an eight-week training period on previously sedentary subjects. A flaw that plagues this study, along with many others is the total work accomplished during each exercise bout is not isocaloric. Gossard, et al.(1986) conducted another study comparing the aerobic capacity adaptations to high- and low-intensity. Unlike the studies by Bhambhani and Singh, Belman and Gaesser, and Gossard et al., the low-intensity group increased VO_{2max} by 8%, where the high-intensity group increased by 17%. This study demonstrated a direct relationship between the intensity of exercise and the increased VO_{2max}, which the improvement of the high intensity group was twice as large as the low intensity group. It is obvious that improved aerobic capacity is directly related to exercise intensity. However, because of the controversy on the level of intensity, additional research needs to be conducted.

Ventilatory Threshold (VEth)

The ventilatory threshold refers to the noninvasive measurement of metabolic adaptation to moderate to high intensity exercise. The ventilatory threshold occurs at a point of which exercise becomes all too difficult to sustain for a long period of time. The VE_{th} is likely to occur as a result of the build up of lactic acid. Unlike VO_{2max}, few studies have focused on intensity and the occurrence of the VE_{th}. Surprisingly, the criteria for defining VE_{th} continue to be uncertain (Pollock et al., 1998).

However, many studies suggest that VE_{th} distinguish the relationship between production of carbon dioxide and its buffering system for lactic acid.

The training intensity that effects the ventilatory threshold is controversial. In a study by Londeree (1997) at the Department of Health and Exercise Sciences, University of Columbia-Missouri, the effects of four training intensities, ranging from low to high intensity, on VE_{th} were observed. Londeree found no significant differences on VE_{th} among the four intensities. However, he did observe a difference between the sedentary and conditioned groups. The VE_{th} of the sedentary subjects responded more readily to training intensities at or above the lactate threshold, than the conditioned subjects. The findings of Belman and Gaessar (1991) support the idea that intensity is not a factor on VE_{th}. Like Londoree (1997), they also found equally improvements of VE_{th} after high intensity and low intensity training. Similarly, Bhambhani and Singh (1985) researched the effects of low, moderate and high intensities on conditioned and unconditioned subjects. VE_{th} improved equally among all three training intensities, regardless of the initial fitness level. It is important to note that all three training groups performed the same amount of work. Posner et al. (1992), researched older adults exercising at low to moderate intensities, though they did not compare to high intensity training, they found an increased VO_{2max}, however no improvement of VE_{th}. Posner stated that "improved VE_{th} and VO_{2max} is usually seen in young and middle aged subjects following an endurance training program." He believed the increased VO_{2max} was due to the ability of the peripheral muscles to buffer the by-products of glycolysis, which allowed for more total work to be accomplished. Due to the uncertainty of exercise intensity, which significantly changes the VE_{th} and other metabolic parameters, additional research should be conducted.

CHAPTER III

METHODOLOGY

Introduction

Prior to testing, a medical history, for risk factor analysis, was taken. Following the American College of Sports Medicine Guidelines, subjects performed no tests if two or more questions were answered "yes". An informed consent form was presented to, and signed by the student. This consent provided explanations of the test, the risks and discomforts, the responsibilities of the participant, the benefits to be expected, inquiries, and the freedom of consent. The Institutional Review Board of Marshall University obtained approval for all procedures of this study, prior to any testing.

Subjects

Fourteen apparently healthy sedentary females, aged 18-39, from Marshall University volunteered to participate in this study. All subjects reported to the Marshall University Exercise Physiology Laboratory to be familiarized with the policies, procedures and testing environment. A twenty-dollar stipend was presented to the subjects at the completion of the study.

Testing Procedures

Testing procedures were performed on four variables, including maximal oxygen consumption, O_2 Pulse, ventilatory threshold and workload. Testing procedures were performed both before and after the six-week treatment.

Maximal Oxygen Consumption

Cardiorespiratory fitness was tested by measuring the maximal oxygen consumed during exercise (VO_2max). A treadmill was used to provide the exercise stress by increasing the speed and grade. Subjects warmed up at 2.0 mph and zero percent grade for two minutes. The exercise protocol required a one-mile per hour increase in speed to achieve a 3.0-mph speed. After the speed was achieved, the percent grade was increased by two percent each minute until maximal exercise was reached. Additional to oxygen consumption, ventilation, and other metabolic indexes were measured or calculated using a SensorMedics 2900 metabolic cart. Maximal heart rate was measured using a wireless Polar Heart Rate monitor.

O_2 Pulse

O_2 Pulse, an index of stroke volume, was calculated using data from the VO_{2max} treadmill test. Variables used for calculations were heart rate and oxygen consumption.

$$O_2 \text{ Pulse} = \frac{\text{VO2 ml/min}}{\text{Heart Rate}}$$

Ventilatory Threshold

Ventilatory threshold was analyzed by plotting minute ventilation against oxygen consumption (L/min). The percent of VO_{2max}, at which the ventilatory threshold occurred, was calculated by the following equation for statistical data interpretation.

$$\% VO_{2max\ @\ VEth} = \frac{VO2\ @\ VEth}{VO_{2max}} * 100$$

Workload (% Grade)

The measurement of workload was assessed by the maximal grade the subject reached during the treadmill test.

Treatment

The subjects were randomly assigned in two groups after being paired according to initial VO_{2max}. One group performed high intensity exercise and the other group exercised at a moderate intensity. Intensities were determined by using the VO_2 data from the exercise test.

The training period consisted of three workouts per week, for six weeks. Each workout was performed by walking on the treadmill. Following the American College of Sports Medicine Guidelines, the subject expended 300 calories per workout while maintaining a prescribed external work using speed and grade, as calculated by the ACSM metabolic equations (Swain, 1997). The subjects were instructed to perform no additional physical exercise during the entire treatment period.

High Intensity

The high intensity group exercised at 85% of their maximal oxygen consumption. This training was done in intervals, with repeated exercise bouts and work-recovery periods. Altering the speed and grade of the work and work-relief intervals progressively increased the intensity of these workouts. The time it took to expend 300 kilocalories was reduced.

Moderate Intensity

The moderate intensity group exercised at 60% of their maximal oxygen consumption. The exercise prescription was determined in the same manner as the high intensity group, except the percent of VO_{2max} was 60% rather than 85%, by the ACSM metabolic equation for the treadmill. The speed and grade prescription was developed to expend 300 calories at a moderate intensity. The group maintained this intensity throughout the study.

Statistical Analysis

A two-way Analysis of Variance was calculated using software by SAS Institute Inc. All graphs and tables presented in the results were developed using the Microsoft Excel computer program.

A student's t test was used to determine any difference between the demographic data between subjects.

CHAPTER IV

RESULTS

Subject Data

Subject characteristics are shown in Tables 1 and 2. Although 16 subjects started the study, only individuals who completed the six-week training period were included in the final analysis (n=14). The data suggest that the groups were heterogeneous with respect to the demographics for the match groups. Mean age of the high intensity group (HI) (n = 7) was 18.9 ± 1.1, which was not a significant difference ($t = 0.082$, $p > .05$) when compared to the moderate intensity group (MI)(n = 7) (23.4 ± 8.3). Mean height and weight did not significantly differ between groups. Height (inches) of subjects averaged 65.9 ± 2.3 in MI and 66.3 ± 2.3 in HI ($t = 0.382$, $p > .05$). Weight (kilograms) averaged 65.9 ± 2.3 in MI and 66.3 ± 2.3 in HI ($t = 0.240$, $p > .05$). Baseline maximum $V0_2$ was also not significantly different ($t = 0.310$, $p > .05$) in MI compared to HI at the beginning of the study.

Oxygen Consumption

As a marker for maximal effort by the subject during the treadmill test, the respiratory exchange ratio (RER) was used. An RER greater than 1.1 is an indicator of maximal effort. During the pre-test, the MI group achieved a mean RER value of 1.25 ± 0.09 and the HI group averaged an RER value of 1.25 ± 0.11. The post-test mean RER value achieved by MI was 1.17 ± 0.05, and the RER of the HI group was 1.18 ± 0.07.

Table 1

Age and Physical Characteristics

for the Moderate Intensity Group

Subjects	Age (years)	Height (in.)	Weight (kg)	Race
BA	21	64	63.64	Caucasian
JB	18	64	48.18	Caucasian
SC	19	68	54.55	Caucasian
KD	18	68	129.77	Caucasian
LG	19	69	58.18	Caucasian
MM	19	64	72.73	Caucasian
LK	18	64	76.36	Caucasian
M	18.86	65.86	71.82	
SD	1.07	2.34	27.36	

t > .05

Table 2

Age and Physical Characteristics

for the High Intensity Group

Subjects	Age (years)	Height (in.)	Weight (kg)	Race
JH	20	67	66.36	Caucasian
HM	18	64	64.55	Caucasian
NR	18	66	72.73	Caucasian
MK	31	63	62.50	Caucasian
HC	19	67	57.73	Caucasian
MM	19	67	59.55	Caucasian
MA	39	70	65.68	Caucasian
M	23.43	66.29	64.16	
SD	8.26	2.29	4.94	

t >.05

The pre-test average $V0_{2max}$ for MI was 30.50 ± 6.45 and the HI averaged 30.11 ± 4.93. The mean $V0_{2max}$ of the MI group, during the post-test, was 32.19 ± 1.42. The HI group averaged a V02max of 32.35 ± 2.00. There was no significant difference between the HI and MI groups ($F = 0.60$ (1, 12), $p = 0.97$), however there was a significant difference in the within-subject comparison of the pre- and post-tests for VO_{2max}. ($F = 48.6$ (1, 12), $p = 0.01$). The MI group improved by 6% between the pre- and post-tests, and the HI improved by 7%. Results for pre- and post-test $V0_{2max}$ are displayed in Tables 3 and 4 and Figures 1 and 2.

0_2 Pulse

O_2 Pulse is an indirect measurement of stroke volume. Mean O_2 Pulse for the MI intensity group was 9.11 ± 1.66, during the pre-test. The HI group yielded an average O_2 Pulse of 7.98 ± 8.43. For the post-test, MI exhibited a mean O_2 Pulse of 9.52 ± 1.76, and the HI averaged an O_2 Pulse of 8.43 ± 0.93. There was no significant difference between HI and MI ($F = 2.31$ (1,12), $p = .15$). However, there was a significant difference within the subject comparison. The mean 0_2 Pulse results of the post-tests were significantly higher than the pre-tests ($F = 29.78$ (1,12), $p = 0.0001$). Also, MI improved by 5% between pre- and post-tests and HI improved by 6%. Results for pre- and post-test O_2 Pulse are displayed in Tables 5 and 6.

Ventilatory Threshold (% $V0_{2max}$)

The mean Ventilatory threshold (VEth) for MI was 68.19% ± 3.53 during the pre-test, and the HI averaged a VEth of 68.62% ± 8.61. For the post-test the MI group yielded a mean VEth of 69.96% ± 3.22, where the HI group averaged a VEth of 70.75% ± 6.26.

Table 3

VO_{2max} Results

Moderate Intensity

Subjects	Pre-VO_{2max}	Post-VO_{2max}	Difference
BA	28.56	30.93	2.37
JB	36.69	40.65	3.96
SC	30.51	30.54	0.03
KD	19.58	20.94	1.36
LG	38.38	38.50	0.12
MM	33.43	36.10	2.67
LK	26.32	27.65	1.33
M	30.5	32.19	1.69
SD	6.45	6.81	1.42
% Improvement	6		

Table 4

VO_{2max} Results

High Intensity

Subjects	Pre-VO_{2max}	Post-VO_{2max}	Difference
JH	28.32	33.20	4.88
HM	34.88	36.25	1.37
NR	30.23	31.15	0.92
MK	23.12	23.71	0.59
HC	37.42	41.17	3.75
MM	30.80	35.06	4.26
MA	26.00	25.92	-0.08
M	30.11	32.35	2.24
SD	4.93	6.03	2.00
% Improvement	7		

With-in Subject Comparison of VO2max

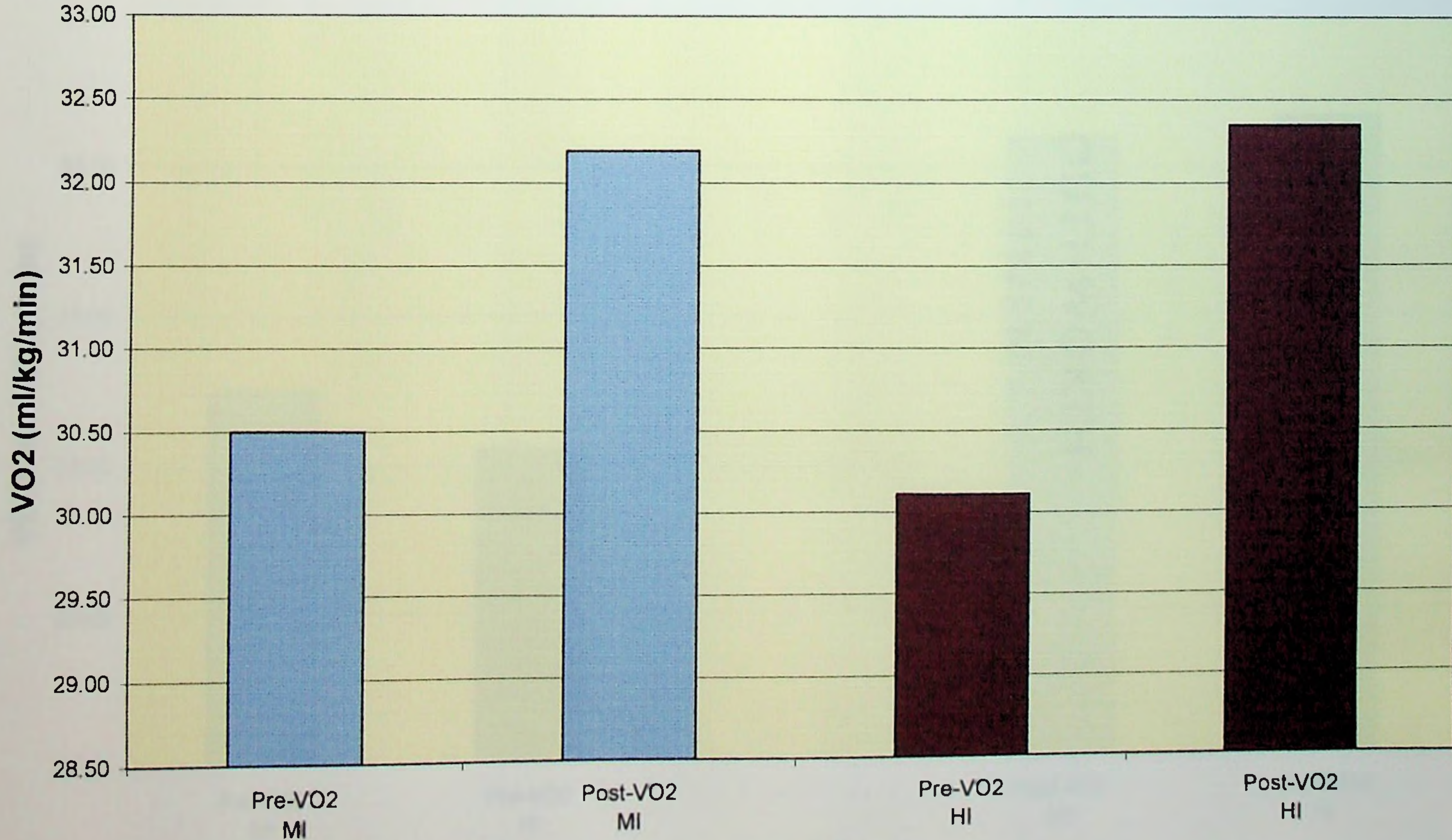

Figure 1

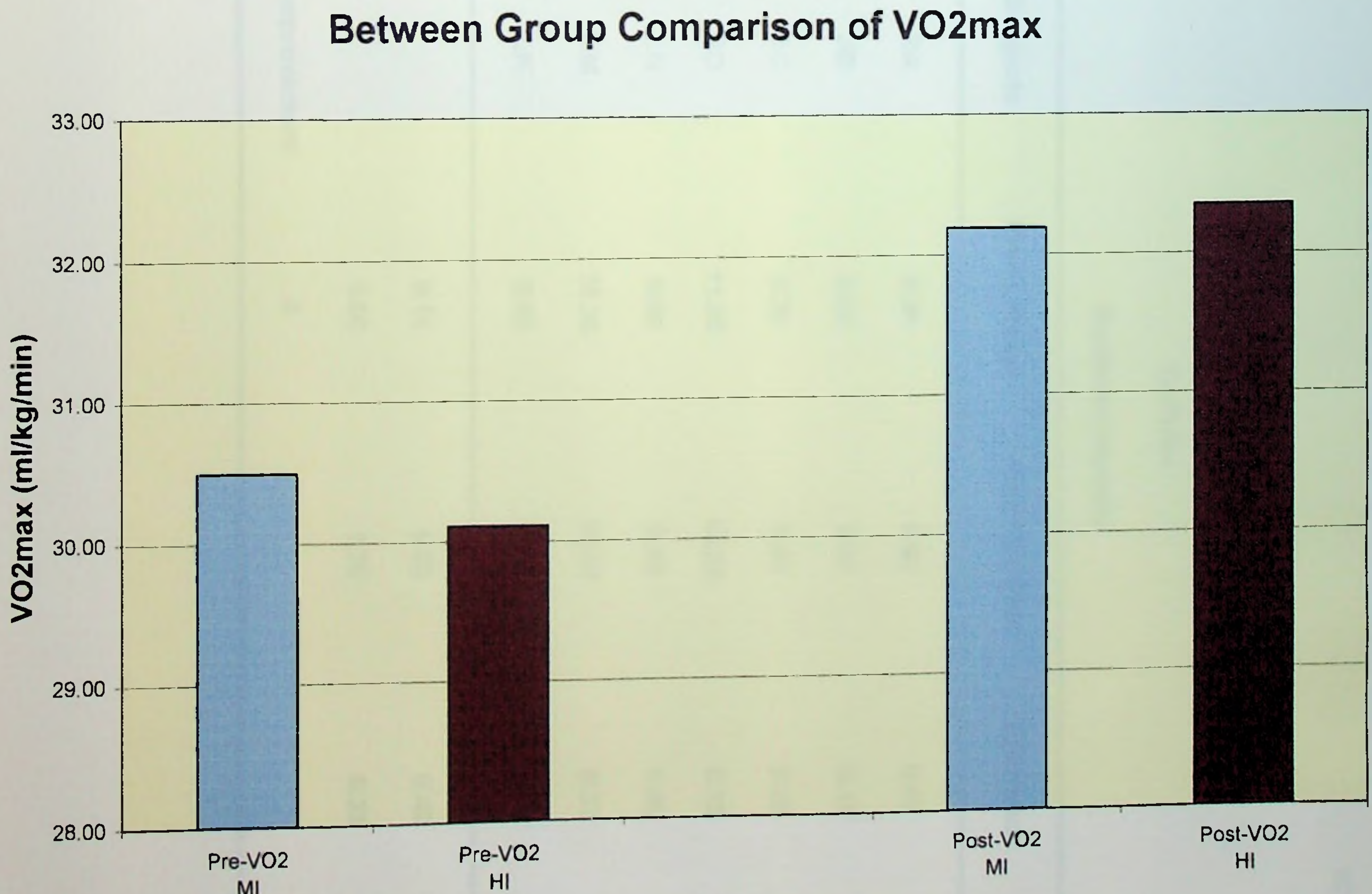
Between Group Comparison of VO2max
VO2max (ml/kg/min)
33.00
32.00
31.00
30.00
29.00
28.00
Pre-VO2 MI
Pre-VO2 HI
Post-VO2 MI
Post-VO2 HI

Figure 2

Table 5

O_2 Pulse

Moderate Intensity

Subjects	Pre-O_2 Pulse	Post-O_2 Pulse	Difference
BA	9.20	9.62	0.42
JB	8.00	7.90	-0.10
SC	6.30	6.80	0.50
KD	11.50	12.20	0.70
LG	8.90	9.80	0.90
MM	10.30	10.67	0.37
LK	9.55	9.68	0.13
<u>M</u>	9.11	9.52	0.42
<u>SD</u>	1.66	1.76	0.33
% Improvement	5		

Table 6

O_2 Pulse

High Intensity

Subjects	Pre-O_2 Pulse	Post-O_2 Pulse	Difference
JH	6.90	7.60	0.70
HM	8.60	9.10	0.50
NR	8.40	9.00	0.60
MK	6.47	6.85	0.38
HC	8.78	9.15	0.37
MM	8.58	9.18	0.60
MA	8.16	8.11	-0.05
M	7.98	8.43	0.44
SD	0.92	0.93	0.25
% Improvement	5		

No significant difference occurred between MI and HI (F = 0.05 (1,12), p = .8323). Likewise, there was no difference in the within-subject comparisons of the pre- and post-tests (F = 2.08 (1,12), p = .1750). Both groups had a 3% improvement of VEth. Results for pre- and post-test VEth are displayed in Tables 7 and 8.

Workload (% Grade)

The mean percent grade for MI was 17.43% ± 4.28, and HI averaged 17.17% ± 3.35 during the pre-test. Following the six-week training period, MI averaged 17.86% ± 4.84 on the treadmill test. HI averaged 20.07% ± 1.74. The two groups did not significantly differ (F = 0.43 (1,12), p = .5265), nevertheless there was a significant difference within the subject comparison (F = 5.917 (1,12), p = .0309). Both groups increased the amount of work they could perform subsequent to the training period. MI improved the amount of workload by 2%, where HI improved by 13%. Tables 9 and 10 display the results for Workload.

There was no significant weight change between MI (t =0.268, df = 6) and HI (t = 0.070, df = 6), nor was there a difference in the within-subject comparison for the pre- and post-tests (t = 0.154, df = 12). Therefore, the amount of work on the treadmill was reflected by percent grade, independent of changes in the weight of the subjects.

Statistical results for the comparison of moderate and high intensity are found in Table 11. Table 12 displays the statistical results for the within subject comparison.

Table 7

Ventilatory Threshold Results (% VO_{2max})

Moderate Intensity

Subjects	Pre-VE_{th}	Post-VE_{th}	Difference
BA	65.21	65.26	0.05
JB	71.00	69.00	-2.00
SC	72.40	70.40	-2.00
KD	72.90	67.80	-5.10
LG	65.71	69.15	3.44
MM	65.71	74.23	8.52
LK	64.40	73.88	9.48
M	68.19	69.96	1.77
SD	3.73	3.22	5.57
% Improvement	3		

Table 8

Ventilatory Threshold Results (% VO_{2max})

High Intensity

Subjects	Pre-VE_{th}	Post-VE_{th}	Difference
JH	72.90	69.26	-3.64
HM	53.67	63.79	10.12
NR	81.00	82.99	1.99
MK	65.01	70.70	5.69
HC	74.02	73.90	-0.12
MM	65.90	66.54	0.64
MA	67.86	68.08	0.22
M	68.62	70.75	2.13
SD	8.61	6.26	4.49
% Improvement	3		

Table 9

Workload Results (% Grade)

Moderate Intensity

Subjects	Pre-WL	Post-WL	Difference
BA	16	16	0
JB	22	22.5	0.5
SC	16	14	-2
KD	10	10	0
LG	22	22	0
MM	20	22.5	2.5
LK	16	18	2
M	17.43	17.86	0.43
SD	4.28	4.84	1.48
% Improvement	2		

Table 10

Workload Results (% Grade)

High Intensity

Subjects	Pre-WL	Post-WL	Difference
JH	16	18	2
HM	20	22	2
NR	20	20	0
MK	12	20	8
HC	22	22.5	0.5
MM	18	20	2
MA	16	18	2
<u>M</u>	17.71	20.07	2.36
<u>SD</u>	3.35	1.74	2.63
% Improvement	13		

Table 11

Statistical Results

Two-way Analysis of Variance

Moderate vs High Intensity

	DF	F ratio	P
VO_2	1	0.00	0.9732
O_2 pulse	1	2.31	0.1544
VE_{th}	1	0.05	0.8323
Workload	1	0.43	0.5265

Table 11. No significant difference occurred in any of the four parameters measured.

Table 12

Within Subject Comparison

(Pre - Post)

	DF	F ratio	P
VO_2	1	18.06	0.0011
O_2 Pulse	1	29.78	0.0001
VE_{th}	1	2.06	0.1750
Workload	1	5.97	0.0309

Table 12. VO_2, O_2 Pulse, and Workload had significant differences within subjects between pre and post tests. VE_{th} had no significant difference within subjects.

CHAPTER V

DISCUSSION

Although the metabolic and cardiovascular responses to exercise have been the subject of numerous studies in recent years, an understanding of the exercise intensity levels necessary for physiological adaptation remains incomplete. This study measured multiple physiological parameters to evaluate the effects of two training intensities on fourteen apparently healthy females. The results were comparable to previous studies assessing the effects of moderate and high intensity exercise.

In the present study, the VO_{2max} and O_2 Pulse improved in both the high intensity group and the moderate intensity group, but are not found to be significantly differently between groups. A study by Gaisser and Rich (1984) reported similar findings.

Workload was also increased in both groups, which moderate intensity increased by 2% and high intensity increased 13%. A significant increase of ventilatory threshold was expected in the high intensity compared to the moderate intensity; however, VE_{th} did not differ between groups or within groups. Surprisingly, the moderate intensity group improved VE_{th} by 3%, just as the high intensity group. A study by Posner et al. in 1992 also showed an improved VE_{th} of 3.5% in low to moderate intensity endurance training. A study by Bhambhani et al. in 1985 researched the VE/VO_2 ratio, which is proportionate to the ventilatory threshold. They, too, had no significant difference between high and low intensity groups. These results show that since the oxygen consumption and workload did improve, and the ventilatory threshold did not change, the biological adaptations were more likely a result of the cardiovascular system, rather than the ventilatory controls. Nevertheless, no significant differences occurred between the high intensity and moderate intensity groups in any of the measured parameters in this study.

Benefits of High Intensity and Moderate Intensity Training

Although exercise intensity produced no difference between groups, with respect to the measured parameters, a comparison can be made when considering the duration of workout. The average treadmill time, for expending the recommended 300 kilocalories, was 49.71 for the moderate intensity group. The high intensity group averaged 38.43 minutes. Figures 3 and 4 display the results of workout duration. The moderate intensity workout was 23% longer in duration than the high intensity. Consequently, in a fast-paced society where the rate of inactivity remains high, despite the urgency of education on physical fitness and physical activity, the 11.29 minutes difference between high intensity and moderate intensity workouts may be very important. Busy lifestyles and lack of time, due to high demand careers and child rearing responsibilities, are partly determining America's increasingly sedentary and unfit population. For this reason, the high intensity exercise training may be more applicable to the lifestyle of the busy individual.

It is concluded that the benefits of physiological adaptations, for moderate intensity training in previously unfit subjects, are equal to the high intensity training. Therefore, it is the responsibility of the individual to choose the preferred training program. Moderate intensity training may be more desirable to sedentary individuals, or individuals of special populations. In those of high-risk groups, a correlation has been made that as the intensity of training increases, the risk of cardiovascular complications likewise increase (Oldridge, Foster, & Schmidt, 1989). Furthermore, a low risk of orthopedic injuries has

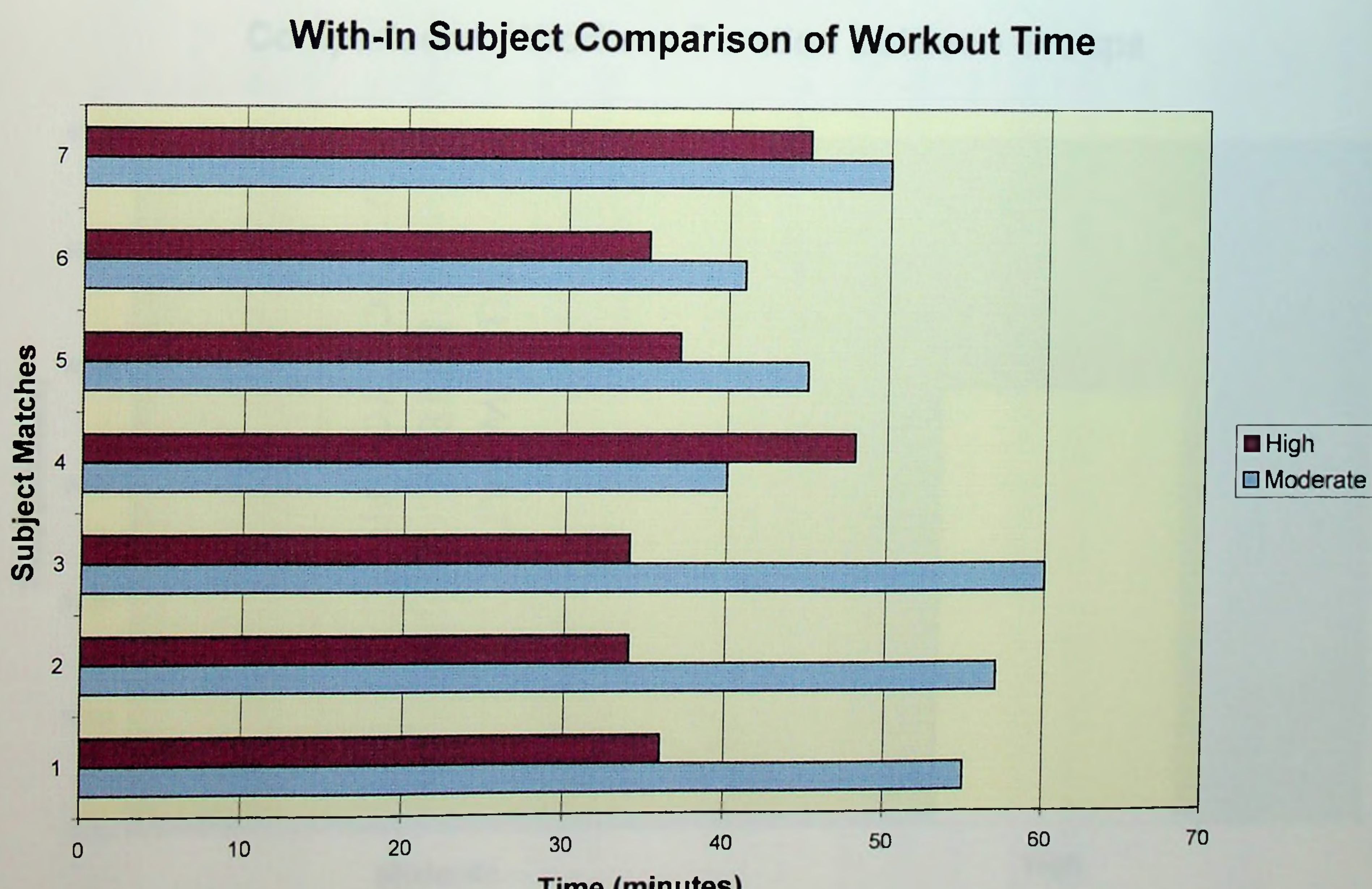
With-in Subject Comparison of Workout Time
Subject Matches
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
Time (minutes)
High
Moderate

Figure 3

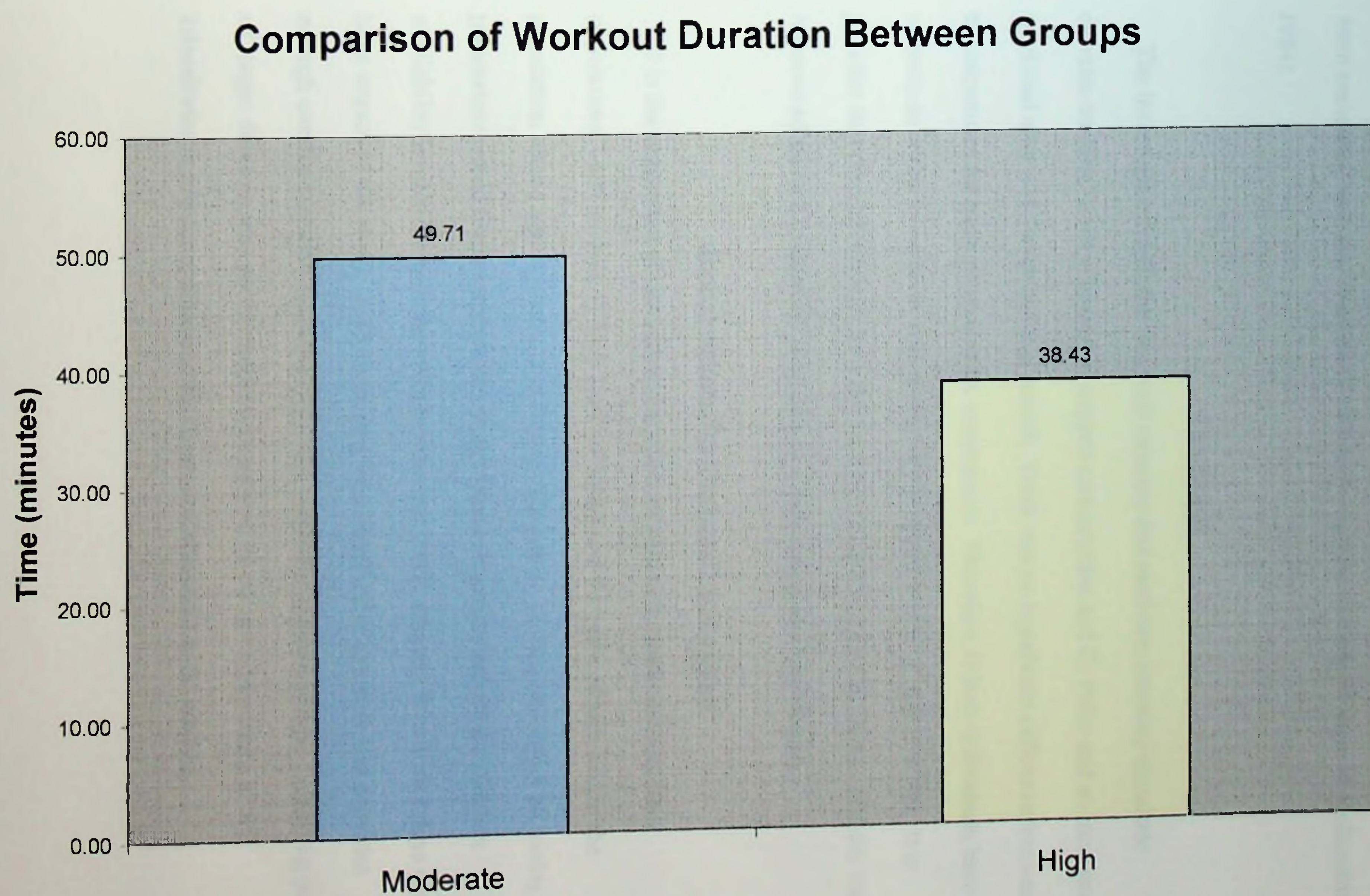
Comparison of Workout Duration Between Groups
Time (minutes)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
49.71
38.43
Moderate
High

Figure 4

been associated with low to moderate intensity exercise training (Wenger & Hellerstein, 1984).

Conclusion

The investigator concludes that high intensity and moderate intensity isocaloric exercise training result in improved oxygen consumption and O_2 Pulse and an increased workload after a six-week training period. There was no significant difference between the intensities for basic physiological adaptations. Therefore, if busy individuals have no contraindications to exercise, a high intensity program would be more suitable. It is possible that prescribing high intensity workouts to achieve similar fitness benefits may improve adherence to exercise programs in a time conscience population.

Improvements, Problems, and Suggestions

It is the suggestion of the author that cross validation be performed on other populations, such as those of high levels of fitness, of the male gender, and of the population whose age is greater than twenty-five years. Testing additional physiological parameters would likely improve the study when comparing intensities. Subject availability limited the training to three times per week, whereas four or five days may have improved the study. Also, there may be a threshold of intensity that provides enough overload to show cardiovascular and metabolic improvements. A training period of longer duration may permit subjects to achieve an energy expenditure of 300 kilocalories in less time, allowing this theoretical threshold to be reached.

APPENDIX A

INFORMED CONSENT FOR TESTING AND PARTICIPATION

Informed Consent to Participate in Research for the Cardiovascular and Metabolic Adaptations to High Intensity and Moderate Intensity Isocaloric Exercise

1. **Procedures**

I understand that in order to be a subject in this study, I must participate in a battery of exercise tests in the Marshall University Exercise Physiology Laboratory. I understand that I will perform these exercise tests both before and after a six-week exercise training program.

I realize that I must participate in a six-week exercise program and follow the exact exercise prescription provided. I also understand that I am not to participate in any other exercise program during the entire data collection and six-week exercise program. In addition, I accept that I must not manipulate my current diet in any way.

To examine fitness of my heart and lungs, I will perform a maximal exercise test on a treadmill, using my greatest effort. I understand that my heart rate will be monitored by a wireless heart rate monitor, and my caloric expenditure will be monitored by a gas analysis system by collecting expired air.

To measure body composition, I understand that skinfold calipers will be placed on the tricep, the suprailliac, and the thigh. These locations do not require the removal of any articles of clothing. I also know that my height and weight will be measured.

I understand that I can stop these tests at any time, and for any reason.

2. **Risks and Discomforts**

I may experience some shortness of breath during the maximal exercise test, and while I am exercising during the six-week exercise program. The sensation will be very similar to the sensation I feel when exercising at a hard intensity.

____________________________ ________________

Subject's Signature Date

____________________________ ________________

Witness Date

During the exercise testing or six-week exercise program, injury may result from stumbling or falling. However, every precaution will be taken to prevent this from occurring. I also may experience slight discomfort from the mouthpiece and headgear worn during the maximal exercise test.

3. **Benefits**

   By participating in this study, I will obtain information regarding my fitness. I will also be provided with personal training during the six-week exercise program. The information about my fitness and my exercise prescription may encourage me to include exercise as part of a healthy lifestyle.

4. **Confidentiality**

   I agree that information gathered from this study may be used in scientific settings. This includes presentations and publications. I understand that my identity will remain confidential to the extent the law allows.

5. **Other Considerations**

   I have been advised that if I have any questions concerning this study, I may contact Dr. Terry Shepherd at 696-2925. If I have any questions regarding my rights as a participant in this study, I may call Dr. Henry Driscoll at 696-7320.

   In the event of any illness or injury, the costs of any medical care are my responsibility. No other compensation is available. In no event will other payment or compensation, financial or otherwise, be offered or made by Marshall University, Marshall University Exercise Physiology Laboratory or the investigators.

______________________________ ______________

Subject's Signature Date

______________________________ ______________

Witness Date

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