A Comparison of Physiological and Perceptual Responses Generated by Riding a Stationary Upright and Recumbent Bicycle

Amy E. Geib
Western Michigan University

A COMPARISON OF PHYSIOLOGICAL AND PERCEPTUAL RESPONSES GENERATED BY RIDING A STATIONARY UPRIGHT AND RECUMBENT BICYCLE

by

Amy E. Geib

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Amy E. Geib, M.A.

Western Michigan University, 2002

The study compared the effects of cycling at three different cadences and three different workloads on a stationary upright and stationary recumbent bicycle on the following variables: (a) heart rate, (b) heart rate as a percentage of maximum heart rate, (c) relative VO_2, (d) relative VO_2 as a percentage of VO_2 max, (e) absolute energy cost, (f) RPE legs, and (g) RPE overall. Heart rate, relative VO_2, R values, and RPE were measured as 18 subjects completed 18 experimental conditions in random order. The experimental conditions consisted of cycling on the stationary upright bicycle (Lifecycle® 9500) and stationary recumbent bicycle (Lifecycle® 9500R) at three pedaling frequencies--60, 70, and 90 rpm, and three workloads--65, 89, and 121 watts. A 3 x 3 x 2 repeated measures ANOVA analysis revealed physiological and perceptual variables increased significantly ($p \leq .05$) as cadence was increased. Additionally, a significant first order interaction effect occurred for all physiological and perceptual variables for resistance by bike. At 65 watts, physiological and perceptual responses were greater on the upright bike. At 89 watts and 121 watts, physiological and perceptual variables were greater on the recumbent bicycle.

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CHAPTER I

INTRODUCTION

More and more Americans are becoming aware of the benefits of physical activity and are seeking a wide array of options to engage in aerobic exercise. Stationary bicycle riding provides individuals the opportunity to improve cardiovascular fitness and training with relatively little strain or stress placed on knee, hip, and ankle joints (LifeFitness, 2000). Providing many of the benefits of outdoor cycling, stationary cycling has the added advantage of being available day or night, in all types of weather, and without the risks of riding on the road. The low impact nature of stationary cycling makes it appropriate for all exercisers, including beginners, those with medical conditions, and fitness enthusiasts.

There are two basic types of stationary bicycles: upright and recumbent. The upright bicycle places the rider in a standard bike-riding position. This position uses the quadriceps, hamstrings, gluteal, and gastrocnemius muscles to propel the pedal crank (Burke, 1986). The recumbent stationary bicycle is lower to the ground and has a large seat with a backrest. The riding style changes, slightly elevating the rider's legs. The rider's legs and feet move in front of the body instead of beneath like in upright cycling (LifeFitness, 2000). This position works the gluteal and hamstring muscles more than traditional bicycles. This riding position also places less strain on the knees and is suitable for people with back problems.

Both types of bicycles allow the rider to adjust workload resistance to vary the intensity of the workout.

LifeFitness manufactures and distributes a comprehensive line of Lifecycle® stationary bicycles. The Lifecycle® 9500 (upright) and 9500R (recumbent) are among the most popular commercial products. The resistance levels for both models range from 0 to 12, 0 providing the least resistance and 12 providing the most. A resistance setting of 0 corresponds to 33 watts and a resistance setting of 12 corresponds to 338 watts regardless of pedaling frequency.

Significance of the Study

As with most exercise modalities, improvements are continuously being made to stationary exercise bicycles. As improved styles of stationary bicycles are designed and introduced to the market place, there is a need for more research concerning the physiological benefits of cycling at different workloads and cadences in different body positions.

Statement of the Problem

The study compared the physiological and perceptual responses to cycling at three different cadences, 60, 70 and 90 revolutions per minute (rpm), and three workloads, 65, 89, and 121 watts (low, medium, and medium high), on a Lifecycle® 9500 stationary upright bicycle and a Lifecycle® 9500R stationary recumbent bicycle. Heart rate (HR), % max HR, relative oxygen consumption (VO_2), % VO_2 max, and absolute energy cost (kcal·min^{1}) were the physiological responses measured. Rating of perceived exertion (RPE) for the legs and overall body during each trial were the perceptual responses measured.

Delimitations

The following delimitations were identified for the study:

1. Western Michigan University students between the ages of 18 and 35 years, considered "low risk" (American College of Sports Medicine, 2000), volunteered as subjects.

2. The subjects were free of musculo-skeletal injuries.

3. The subjects engaged in regular aerobic exercise (20 minutes of activity, 2-3 times per week).

4. The use of a metabolic cart measured two dependent variables: oxygen consumption (VO_2) and energy cost (kcal·min^{-1}).

5. Subjects randomly performed one trial for each condition.

Limitations

The following limitations could affect the interpretation of the results of the study:

1. The subjects were 18 to 35 years old and may not be representative of the general population, which could affect the external validity.

2. Subjects only performed one trial for each of the 18 experimental conditions.

3. Subjects performed six conditions per session and may have experienced

fatigue.

Assumptions

The following assumptions were made for this study.

1. The resistance settings between the Lifecycle® 9500 stationary upright bicycle and the Lifecycle® 9500R stationary recumbent bicycle represented equal workloads.

2. Subjects were sufficiently warmed up before performing each condition.

3. Subjects accurately reported RPE values.

4. Subjects recovered adequately between conditions.

Research Hypotheses

The following hypotheses were evaluated in this study:

1. The recumbent bicycle will yield a higher rating of perceived exertion (RPE) for legs and overall body than the upright bicycle for all conditions.

2. The recumbent bicycle will yield greater oxygen consumption than the upright bicycle for all conditions.

3. The recumbent bicycle will yield a greater energy cost than the upright bicycle for all conditions.

4. The recumbent bicycle will yield a greater heart rate response than the upright bicycle for all conditions.

Definitions

The following terms were defined for this study:

1. *Borg's rating of perceived exertion (RPE) scale*: A scale, with values ranging from 6 (no exertion) to 20 (maximal exertion), developed by G. A. Borg, that can be used to establish exercise intensity for the purpose of training (McArdle, Katch & Katch, 2000).

2. *Energy cost*: A calculated value that estimates the amount of energy needed to complete the exercise.

3. *Maximal oxygen consumption (VO_2 max)*: An individual's capacity for aerobically resynthesizing ATP (McArdle, et al., 2000).

4. *Oxygen consumption (VO_2)*: A measure of a person's ability to take in and use oxygen (McArdle, et al., 2000).

5. *Respiratory exchange ratio (R)*: The ratio of carbon dioxide produced to oxygen consumption when the exchange of oxygen and carbon dioxide at the lungs no longer reflects actual gas exchange from nutrient metabolism in the cell. R values are representative of substrate utilization during steady state exercise; a value of 1.0 represents 100% carbohydrate metabolism, and 0.7 represents 100% fat metabolism (McArdle, et al., 2000).

CHAPTER II

REVIEW OF LITERATURE

Introduction

Indoor stationary bicycle riding has become a popular means of cardiovascular exercise for many Americans, not just elite cyclists. Stationary upright and recumbent bicycles provide riders with a challenging aerobic workout with minimal stress on hip, knee and ankle joints.

The design of an upright bicycle, much like a traditional bicycle, places emphasis on the quadriceps, hamstrings, gluteal, and gastrocnemius muscles. A recumbent bicycle places the rider lower to the ground with the legs moving in front of the body. This design places more emphasis on the gluteal and hamstrings muscles than does an upright bicycle.

While much research has been done comparing and contrasting muscle recruitment employed between these two bicycles and body positions, few studies have explored the perceptual and physiological responses to different cadences and resistance settings between these bicycles.

This chapter contains the following sections: (a) guidelines for cardiovascular exercise, (b) perceptual responses to cardiovascular exercise, (c) physiological responses to cardiovascular exercise, (d) indirect calorimetry, (e) cardiovascular exercise machine research, (f) bicycle research, and (g) summary.

Guidelines for Cardiovascular Exercise

The American College of Sports Medicine (ACSM), the Centers for Disease Control, and the American Heart Association recognize the health benefits associated with regular cardiovascular exercise. These benefits include a reduced risk for coronary artery disease, stroke, some cancers, diabetes, and other diseases (ACSM, 2000). Therefore, the ACSM recommends that adults engage in cardiovascular or aerobic exercise, defined as any activity using large muscle groups rhythmically and continuously (e.g. running, cycling, swimming, etc.), three to five days per week for 20 to 60 minutes per session in order to improve cardiovascular fitness. The intensity should be 55 to 90% of maximum heart rate, 40 to 85% of heart rate reserve, or 50 to 85% of VO_2 maximum. The ACSM recommends a target range of 150 to 400 kilocalorie expenditure per physical activity session. The intensity, duration, and frequency of aerobic exercise should be gradually increased as appropriate (ACSM, 2000).

Perceptual Responses to Cardiovascular Exercise

Ratings of perceived exertion (RPE) is a valuable indicator for monitoring an individual's exercise tolerance (American College of Sports Medicine, 2000). Borg's RPE scale was developed to allow the exerciser to subjectively rate his or her feelings during exercise, taking into account personal fitness level, environmental conditions, and general fatigue levels (ACSM, 2000). Borg's original RPE scale ranged from 6 (no exertion) to 20 (maximal exertion). Each of the numbers corresponded to a person's perceived level of work. For example, a rating of 9 is perceived as "very light" work while a rating of 19 is perceived as "very hard" work.

It has been found that a cardiorespiratory training effect and the threshold for blood lactate accumulation are achieved at a rating for "somewhat hard" to "hard," which approximates a rating of 12 to 16 on Borg's RPE scale (ACSM, 2000).

Because of its subjectivity, RPE should be used as a guideline in setting exercise intensity and ideally used with heart rate measures to monitor an individual's intensity.

Physiological Response to Cardiovascular Exercise

An individual's need for energy, therefore oxygen, increases when engaging in cardiovascular exercise. Heart rate, respiratory rate, and VO_2 increase during aerobic exercise. The extent to which they increase depends on the frequency, intensity, duration, and type of exercise (ACSM, 2000). As a result of training, the body more efficiently consumes and uses oxygen and better supplies energy to working muscles. Training adaptations to aerobic exercise include: (a) an increase in VO_2 max, (b) a decrease in resting heart rate, (c) an increase in the concentration of aerobic metabolic enzymes, (d) an increase in the concentration of red blood cells, (e) a decrease in blood pressure, and (f) an improved blood lipid and cholesterol profile (ACSM, 2000).

Indirect Caliometry

Direct caliometry is a precise technique for measuring metabolic rates of humans. By measuring the heat produced and released by subjects during rest or exercise, direct caliometry can be used to determine a person's energy expenditure. Being able to calculate energy expenditure is helpful when prescribing exercise for weight loss or management. While direct caliometry is the best means of calculating energy expenditure, the equipment needed is prohibitively expensive and the method is not practical for most situations (Robergs & Roberts, 1997). Therefore, indirect caliometry is most often used.

The principle of indirect caliometry uses the measurement of oxygen consumption (VO_2) to determine the metabolic rate. The most common method of measuring oxygen consumption employs open-circuit spirometry. The subject inspires room air and expires gas into a gas collection system, which measures the volume of air and the fraction of oxygen and carbon dioxide (CO_2) in the expired air. An integrated metabolic cart with a computer interface calculates the VO_2 consumption and CO_2 production (VCO_2) rates (Robergs & Roberts, 1997). The metabolic cart must be calibrated using a known concentration of O_2 and CO_2 before testing and gas collection begin (Robergs & Roberts, 1997).

Energy cost in kilocalories can be estimated by using the respiratory quotient (RQ). Both respiratory exchange ratio (RER) and respiratory quotient (RQ) are calculated as VCO_2/VO_2. RER is a ventilatory measurement and reflects gas energy expenditure, the equipment needed is prohibitively expensive and the method is not practical for most situations (Robergs & Roberts, 1997). Therefore, indirect caliometry is most often used.

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Energy cost in kilocalories can be estimated by using the respiratory quotient (RQ). Both respiratory exchange ratio (RER) and respiratory quotient (RQ) are calculated as VCO_2/VO_2. RER is a ventilatory measurement and reflects gas exchange between the lungs and pulmonary blood. Respiratory quotient is a measurement based solely on cellular respiration and is equivalent to RER only under steady-state conditions. RQ provides information about substrate utilization at the cellular level, equaling 1.0 for carbohydrate oxidation, 0.7 for fat oxidation, and approximately 0.8 for protein oxidation (ACSM, 2000).

The energy expenditure associated with a given level of oxygen uptake varies slightly with the RQ value. Energy expenditure is about 4.69 $kcal \cdot L^{-1}$ of O_2 at an RQ of 0.7, and 5.05 kcal·L^{-1} of O_2 at an RQ of 1.0 (ACSM, 2000). When RQ is not known, the value of 5 kcal·L^{-1} of O_2 is often used.

Cardiovascular Exercise Machine Research

Numerous types of stationary exercise machines are available to help improve or maintain cardiovascular fitness. Studies comparing various exercise machines are reviewed in this section.

Hagerman, Lawrence, and Mansfield (1988) compared energy expenditure during rowing and cycling ergometry. Subjects performed four graded exercise tests (GXT), two on the cycle ergometer (CGXT) and two on the rowing ergometer (RGXT) in a randomized order. Each GXT began at 50 watts and power was increased progressively every two minutes until test termination. During each test, a metabolic cart was used to measure VO_2 and R values.

A repeated measures ANOVA analysis showed VO_2 values were significantly higher ($p<0.01$) for rowing than for cycling. Likewise, heart rates were significantly higher ($p<0.01$) for rowing than for cycling. These findings reflect previous research that indicates the rowing action requires the use of larger muscle mass to sustain exercise. It is well known that the addition of more muscle involvement in an exercise increases the oxygen cost.

There is also the possibility that lack of familiarity with the rowing exercise may have contributed to a higher metabolic response during rowing as opposed to the lower response noted for the more familiar cycle exercise. There is also speculation that cardiovascular responses during rowing may reflect the unique postural changes that accompany this exercise (Mahler, et al., 1987).

The research conclusion was that rowing exercise places a greater demand on the aerobic energy system than some of the more traditional exercises such as cycle ergometry. However, Hagerman et al. indicated subjects appeared more confident during cycling, especially at higher exercise intensities.

Zeni, Hoffman, and Clifford (1996) compared rates of energy expenditure at given ratings of perceived exertion levels among six different indoor exercise machines: (1) Airdyne stationary bicycle, (2) simulated cross-country skier, (3) cycle ergometer, (4) rowing ergometer, (5) stair stepper, and (6) treadmill. Subjects exercised on each machine for 15 minutes. Five minutes were performed at a self-selected rate corresponding to an RPE level of 11 (fairly light). Five minutes were performed at a self-selected rate corresponding to an RPE level of 13 (somewhat hard), and five minutes were performed at a self-selected rate corresponding to an RPE level of 15 (hard). Heart rates were continuously averaged during 15-second intervals. During the final minute of each exercise stage, expired gases were collected. Calculated VO_2 values were subsequently converted to rates of energy expenditure. Immediately after each exercise stage, blood lactate concentrations were analyzed.

According to Zeni, Hoffman, and Clifford (1996), a repeated measures analysis showed there were significant differences ($p<.001$) among machines with mean rates of energy expenditure varying by as much as 261 $kcal \cdot hr^{-1}$. The treadmill induced significantly higher rates of energy expenditure compared with all other exercise machines tested at given RPE levels. Simulated cross-country skiing, rowing ergometry, and stair stepping induced significantly higher rates of energy expenditure compared with the Airdyne stationary bike and cycle ergometer. Heart rates were significantly ($p<.001$) different among exercise machines, with mean values varying up to 26 beats per minute at a given RPE.

The study concluded that the treadmill yielded the greatest energy expenditure and cardiorespiratory training stimulus. In general, use of a large muscle mass appears to allow a greater metabolic demand for a given RPE than exercise with a smaller muscle mass. However, muscle mass is not the only factor determining the relationship between metabolic demand and RPE. Factors related to the movement pattern of the exercise, such as the degree to which eccentric and isometric contractions are involved, and the familiarity with the movement pattern may be involved.

Bicycle Research

Most of the research related to physiological and perceptual responses to has been conducted on road cycles rather than stationary indoor bicycles. Therefore, the following review discusses findings from research performed on both stationary indoor and outdoor bicycles.

Physiological Responses to Cycling

Grazzi, Alfieri, Borsettto, Manfredini, Mazzoni, and Conconi (1999) examined the power output/heart rate relationship for professional cyclists when environmental conditions were standardized. This research was conducted as a follow up to research that showed a linear relationship between heart rate and cycling speeds. Grazzi, et al. (1999) found a linear relationship between power output and heart rate during an incremental test for professional cyclists at low to submaximal power outputs (100 to 400 watts). At power outputs greater than 400 watts, heart rate responses were no longer proportional to the increase in power output. At this point, known as the deflection point, the relationship became curvilinear.

In a study conducted by Nickleberry and Brooks (1996), the R values increased as a function of power output. The same was true for cycling cadence. Cyclists maintained a higher R value at 80 rpm (0.96 ± 0.01) than at 50 rpm ($0.93 \pm .002$). Likewise, VO_2 values increased with pedaling frequency. Mean VO_2 values were greater at 80 rpm (3.14 ± 0.01 $l{\cdot}min^{-1}$) than they were at 50 rpm (3.08 ± 0.02 $l{\cdot}min^{-1}$).

Perceptual Responses to Cycling

The subjective rating of perceived exertion (RPE) during exercise is thought to depend on both central and peripheral feedback (Cafarelli, 1977). The central input is associated primarily with the cardiorespiratory response to exercise; whereas, the peripheral input is associated with the sensation of muscular and joint strain received from the exercising limbs.

When subjects were asked to rate the central and peripheral effort separately during cycling, the peripheral input was usually predominate (Carafelli, 1977). However, Cafarelli (1977), noted that when subjects reached 50% of their maximal aerobic power, their central input ratings started to increase in relation to the workload. This finding helps support the conclusion that central input may become more important as workload increases. The relationship between workload, pedaling cadence, and the rating of perceived exertion may be summarized by the findings of Lollgen, Ulmer, Gross, Dilbert, and Nieding (1975). They found cyclists preferred a high pedaling cadence for each workload studied. It was also demonstrated that for higher power outputs, the perception of effort decreased at a greater rate as pedaling cadence increased.

Garcin, Vautier, Vandewalle, Wolff, and Monod (1998) investigated the overall rating of perceived exertion (RPE_{ov}) according to the 6-20 scale proposed by Borg (1970) and muscular RPE (RPE_{mu}) in exercises at a constant load. The relationship between RPE and heart rate for three different loads was studied during exhausting exercises in 10 participants. The participants performed cycling exercises up to exhaustion at 60, 73, and 86% maximal aerobic power (MAP) measured during an incremental test. Heart rate, RPE_{ov}, RPE_{mu}, and exhaustion time were measured. Mean RPE increased linearly with time up to exhaustion. The relationships between RPE_{mu} or RPE_{ov} and percentage of exhaustion time were similar for exercises at 60 and 73% MAP although the exhaustion times were very different (79.40 ±30.64 min versus 36.19±15.99 min, respectively) ($p<0.001$). It was likely that RPE was a measure of hardness of exercise rather than the intensity of exercise. In addition, the data of the present study indicated that RPE_{mu} could be more useful than RPE_{ov} in cycling.

Summary

Stationary upright and recumbent bicycles are among the many types of indoor cardiovascular machines available to help individuals meet their aerobic exercise needs. In the research presented, indoor exercise machines such as rowing ergometers or treadmills yielded greater physiological responses than stationary cycles. However, Hagerman et al. indicated subjects appeared more confident during cycling, especially at higher exercise intensities which could contribute to exercise adherence. Furthermore, stationary cycling minimizes joint stress; an advantage it has over machines such as treadmills and stair steppers.

Research conducted using different types of bicycles suggests linear relationships between power output and heart rate at submaximal workloads. The relationships between energy expenditure and power output and cadence, respectively, were also linear. Likewise, linear relationships were found between energy expenditure and power output and cadence, respectively.

Rating of perceived exertion (RPE) tended to be greater in the legs than in the cardiorespiratory system. However, as work load approached and exceeded 50% of subjects' maximal aerobic power, RPE for the cardiorespiratory system increased. For the most part, RPE displayed a linear relationship with work load and cadence. However, there was an inverse relationship for higher cadences; the perception of effort decreased at a greater rate as pedaling cadence increased.

It was likely that RPE was a measure of hardness of exercise rather than the intensity of exercise. In addition, the data indicated that muscular RPE could be more useful than overall RPE in cycling.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The purpose of the study was to compare the physiological and perceptual responses to three different cadences: (1) 60 rpm, (2) 70 rpm, and (3) 90 rpm and three different workloads: (1) 65 watts, (2) 89 watts, and (3) 121 watts on a stationary upright and stationary recumbent bicycle. The physiological variables measured were: (a) Heart rate (HR), (2) HR as a percentage of HR max (% max HR), (3) relative oxygen consumption (VO_2), (4) VO_2 as a percentage of VO_2 max (% of VO_2 max), and (5) absolute energy cost. The perceptual variables measured were rating of perceived exertion (RPE) for legs and RPE overall. Additionally, two VO_2 max tests were completed in order to calculate the percentage of VO_2 and HR achieved by subjects during each experimental condition. The following procedural steps are included in this chapter: (a) selection of subjects, (b) instrumentation. (c) testing procedures, (d) design of the study, and (e) treatment of data.

Selection of Subjects

Eighteen healthy subjects (ACSM, 2000), between 18 and 35 years old, participated in the study. The subjects were recruited from Health, Physical Education, and Recreation classes and the Student Recreation Center at Western

Michigan University (see Recruitment script, Appendix A). Subjects gave written consent prior to participation in the study (see Informed Consent Form, Appendix B) and completed a health screening form (see Par Q, Appendix C) Approval to conduct this study was given by WMU's Human Subjects Institutional Review Board (see Approval letter, Appendix D). Subjects were asked to refrain from consuming a meal and drinks containing caffeine or alcohol two hours preceding each test.

Instrumentation

The equipment for the VO_2 max test consisted of : (a) a Sensormedics metabolic cart, model Vmax 229 LV Lite, Yorba Linda, CA, (b) a four-lead electrocardiogram (EKG), Cardio-soft, GE Marquette Medical Systems, Milwaukee, WI, (c) a Hans Rudolph 1.375 mouthpiece, (d) a BMS® 12-525 blood pressure cuff, (e) an IMCO Elite stethoscope, and (f) A Quinton Instruments model 643 treadmill, Seattle, WA. Borg's Rating of Perceived Exertion (RPE) with a scale of 6 (no exertion) to 20 (maximal exertion) was used as an indicator of the subjects' tolerance to exercise and exhaustion (ACSM, 2000). During the exercise conditions, subjects cycled on a Lifecycle® 9500 stationary upright bicycle and a 9500R recumbent bicycle, Lake Forest, Illinois. The Sensormedics metabolic cart and a Nonin 8600 Pulse Oximeter Sensor, Plymouth, Minnesota, were also used.

Design of the Study

The purpose of this study was to compare the physiological and perceptual responses during exercise on a Lifecycle® 9500 stationary upright and 9500R stationary recumbent bicycle at three different cadences and three different workload settings in random order: (1) 60 rpm, 65 watts, upright, (2) 60 rpm, 65 watts, recumbent, (3) 60 rpm, 89 watts, upright, (4) 60 rpm, 89 watts, recumbent, (5) 60 rpm, 121 watts, upright, (6) 60 rpm, 121 watts, recumbent, (7) 70 rpm, 65 watts, upright, (8) 70 rpm, 65 watts, recumbent, (9) 70 rpm, 89 watts, upright, (10) 70 rpm, 89 watts, recumbent, (11) 70 rpm, 121 watts, upright, (12) 70 rpm, 121 watts, recumbent, (13) 90 rpm, 65 watts, upright, (14) 90 rpm, 65 watts, recumbent, (15) 90 rpm, 89 watts, upright, (16) 90 rpm, 89 watts, recumbent, (17) 90 rpm, 121 watts, upright, and (18) 90 rpm, 121 watts, recumbent. The study was formulated using a repeated measures design.

The dependent variables were: (a) HR, (b) % max HR, (3) VO_2, (4%) VO_2 max, (5) absolute energy cost, (f) RPE for legs, and (g) RPE for overall.

Testing Procedures

Initial Procedures

Testing was completed in the Exercise Physiology Laboratory in the University Recreation Center at Western Michigan University. The testing procedures and possible risks of the study were explained. Subjects wore comfortable clothing and footwear functional for walking or jogging on the treadmill and riding the stationary bicycles. Subjects were given five minutes to become accustomed to the treadmill and bicycles before testing and data collection began.

VO_2 Max Test

Subjects performed a VO_2 max test on the treadmill using the modified Bruce treadmill protocol (ACSM, 2000) on two different days. Subjects walked on the treadmill at 1.7 mph at 0% grade until warmed up.

Once the subjects were sufficiently warmed up, the VO_2 max test began. The treadmill speed and grade increased every three minutes. Subjects' HR, EKG, and VO_2 were monitored continuously throughout the test. Blood pressure was measured and RPE assessed at the second minute of each stage of the test. The subjects terminated the test once they had reached fatigued. The max values for HR and VO_2 from the second max test were used in the study

Bicycle Tests

Subjects participated in three, one-hour sessions, during which they rode both the stationary upright and recumbent bicycle. Before each testing session, subjects warmed up using their own protocol.

During each session, subjects cycled at one of the following resistances in random order: (a) 65 watts, (b) 89 watts, or (c) 121 watts. While riding at each of these resistances, subjects pedaled at three different cadences, in random order: (a) 60 rpm, (b) 70 rpm, and (c) 90 rpm on both the upright and recumbent bicycle. To keep cadence, subjects pedaled in rhythm to the beat of a metronome. Each beat of the metronome corresponded with one half revolution of either the right or left foot. The metronome was set at 120 bpm for a cadence of 60 rpm, at 140 bpm for a cadence of 70 rpm, and 180 bpm for a cadence of 90 rpm.

Subjects exercised at each condition for 5 minutes. A steady state (heart rates within 5 beats of each other) was achieved approximately 3 minutes into each exercise condition. During the last minute of each condition, HR, relative VO_2 and R values were recorded every 20 seconds and averaged for one value for each variable. RPE for legs and overall were recorded at the beginning of the last minute of each condition.

Between each condition, subjects rode without any resistance until their heart rate recovered to 110 bpm. The next experimental condition was performed once HR had recovered to 110 bpm or less. Subjects performed six conditions per session.

Treatment of Data

Measurement of HR, relative VO_2, and R values were recorded once steady state was achieved for each condition. Percent max HR was calculated by dividing each subject's mean HR for each condition by his or her maximum HR, established by the maximal treadmill test, and multiplied by 100. Likewise, % VO_2 max was calculated by dividing each subject's mean VO_2 for each condition by his or her VO_2

max, also determined by the treadmill test, multiplied by 100. Energy cost in kilocalories was calculated using the mean R value for each condition. The subject's absolute VO_2 ($L\ O_2 \cdot min^{-1}$) was multiplied by 5 kcal to determine kilocalories per minute for each condition (ACSM, 2000).

A three-way repeated measures ANOVA (cadence x resistance x bike) was calculated to determine if HR, % max HR, VO_2, % VO_2 max, energy cost, RPE for legs, and RPE overall were different among workloads and cadences between the two bikes. All hypotheses were tested at the .05 level of significance. Statistical Package for Social Sciences version 10.0 computer software was used to calculate the repeated measures ANOVA.

If the assumption of sphericity could not be assumed, the degrees of freedom were adjusted. If Epsilon > .75, the Huynh-Feldt method was used to adjust the degrees of freedom. If Epsilon ≤ .75, the degrees of freedom were adjusted using the Greenhouse-Geisser method. A pairwise comparison, Least Significant Difference, was used to determine the significance of the differences among the means of each dependent variable.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This study compared the physiological and perceptual responses to exercise on Lifecycle® 9500 stationary upright and 9500R stationary recumbent bicycles at three different cadences and three different resistance levels. Subjects participated in 18 experimental conditions. During the final minute of each condition, after a steady state was achieved, data were collected. In this chapter, results for the following are provided: (a) subject demographics, (b) heart rate, (c) % max HR, (d) relative VO_2, (e) % VO_2 max, (f) absolute energy cost per minute, (g) RPE for legs and (h) RPE for overall.

Results

Subject Demographics

Eighteen subjects, 11 females and 7 males, participated in this study. The mean age for females was 22.9 years with a standard deviation of 4.2 years. The mean age for males was 23 years with a standard deviation of 3 years. The mean weight for females was 59 kg with a standard deviation of 4.3 kg. The mean weight for males was 77.9 kg with a standard deviation of 6.6 kg. The female mean height was 1.63 m with a standard deviation of .05 m. The mean height for males was 1.78 m with a standard deviation of .075 m. The mean maximum heart rate was 192 bpm with a standard deviation of 9.58 bpm. The mean relative VO_2 max was 49 $ml \cdot kg^{-1} \cdot min^{-1}$ with a standard deviation of 7.01 $ml \cdot kg^{-1} \cdot min^{-1}$.

Heart Rate

The means and standard deviations for heart rate are included in Appendix E. The repeated measures ANOVA summary for heart rate is presented in Table 1. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. Since the assumption of sphericity could not be met for the main effect, rpm, the degrees of freedom were adjusted using the Huynh-Feldt method. A significant difference was found for the main effect, rpm, $F(1.58, 26.90) = 49.81$, $p<.05$.

2. A significant difference existed for the main effect, resistance, $F(2, 34) = 119.95$, $p< .05$.

3. A significant difference was found for the main effect, bike, $F(1, 17) = 6.09$, $p< .05$.

4. No significant difference existed for the first order interaction effect, rpm by resistance, $F(4, 68)=2.72$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = 1.87$, $p> .05$.

6. Since the assumption of sphericity could not be met for the first order interaction effect, bike by resistance, the degrees of freedom were adjusted using the Greenhouse–Geisser method. A significant difference existed between the first order interaction effect, bike x resistance, $F(1.30, 22.11) = 110.33$, $p < .05$. The interaction effect is represented in Figure 1.

7. No significant difference was found for the second order interaction effect, rpm by resistance by bike, $F(4, 68) = .198$, $p > .05$.

Heart Rate as a Percentage of Maximum Heart Rate

The means and standard deviations for heart rate as a percentage of maximum heart rate are included in Appendix F. The repeated measures ANOVA summary for heart rate as a percentage of maximum heart rate is presented in Table 2. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. Since the assumption of sphericity could not be met for the main effect, rpm, the degrees of freedom were adjusted using the Huynh-Feldt method. A significant difference was found for the main effect, rpm, $F(1.73, 29.44) = 57.96$, $p<.05$.

2. A significant difference was found for the main effect, resistance, $F(2, 34)=120.68$, $p<.05$.

Table 1

ANOVA Summary for Heart Rate

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	1975.56	1.58	1248.33	49.81	.00
Error (Rpm)	674.33	26.90	25.07		
Res (R)	54793.45	2.00	27396.73	119.95	.00
Error (R)	7765.44	34.00	228.40		
Bike (B)	230.03	1.00	230.03	6.09	.02
Error (B)	641.81	17.00	37.75		
Rpm x R	123.90	4.00	30.98	2.72	.17
Error (Rpm x R)	775.88	68.00	11.41		
Rpm x B	58.72	2.00	29.36	1.87	.17
Error (Rpm x B)	534.28	34.00	15.71		
R x B	5668.57	1.30	4358.27	110.33	.00
Error (R x B)	873.43	22.11	39.50		
Rpm x R x B	12.15	4.00	3.0	.20	.94
Error (Rpm x R x B)	1044.52	68.00	15.36		

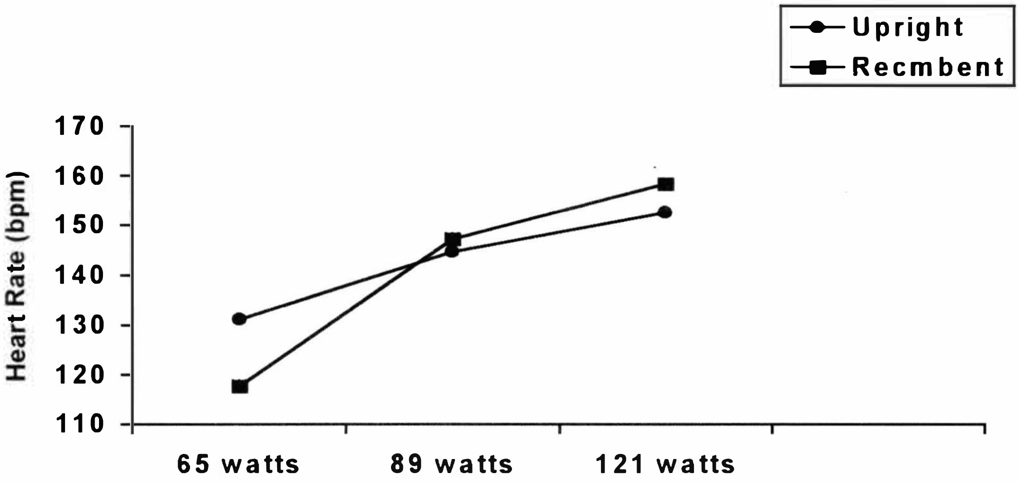

Figure 1. Significant Interaction Effect for Resistance by Bike on Heart Rate

3. A significant difference was found for the main effect, bike, $F(1, 17)=5.91$ $p<.05$.

4. No significant difference was found for the first order interaction effect, rpm by resistance, $F(4, 68) = 2.70$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = 1.49$, $p>.05$.

6. Since the assumption of sphericity could not be met for the first order interaction effect, resistance x bike, the Greenhouse-Geisser method was used to adjust the degrees of freedom. A significant difference existed in the first order interaction effect, resistance by x bike, $F(1.37, 23.32) = 110.84$, $p<.05$. The interaction effect is represented in Figure 2.

7. No significant difference was found for the second order interaction effect, rpm by resistance by bike, $F(4, 68) = .114$, $p>.05$.

Relative VO_2

The means and standard deviations for relative VO_2 are included in Appendix G. The repeated measures ANOVA summary for relative VO_2 is presented in Table 3. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. A significant difference was found for the main effect, rpm, $F(2, 34) = 125.39$, $p<.05$.

2. A significant difference existed for the main effect, resistance, $F(2, 34) = 125.20$, $p<.05$.

3. A significant difference was found for the main effect, bike, $F(1, 17) = 22.47$, $p<.05$.

4. No significant difference existed for the first order interaction effect, rpm by resistance, $F(4, 68) = 2.76$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = .288$, $p>.05$.

6. A significant difference existed for the first order interaction effect, resistance by bike, $F(2, 34) = 182.39$, $p<.05$. Figure 3 illustrates the interaction effect.

7. No significant difference was found for the second order interaction effect, resistance by bike by rpm, $F(4, 68) = .675$, $p>.05$.

Table 2

ANOVA Summary for Heart Rate as a Percentage of Maximum Heart Rate

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	559.04	1.73	322.87	57.96	.00
Error (Rpm)	163.97	29.44	5.57		
Res (R)	14677.05	2.00	7338.52	120.68	.00
Error (R)	206.53	34.00	60.81		
Bike (B)	65.16	1.00	65.16	5.91	.03
Error (B)	187.52	17.00	11.03		
Rpm x R	34.51	4.00	8.63	2.70	.19
Error (Rpm x R)	217.36	68.00	3.20		
Rpm x B	11.28	2.00	5.64	1.50	.24
Error (Rpm x B)	128.30	34.00	3.77		
R x B	1548.55	1.37	1128.95	110.84	.00
Error (R x B)	237.50	23.32	10.19		
Rpm x R x B	1.97	4.00	.49	.11	.98
Error (Rpm x R x B)	295.16	68.00	4.34		

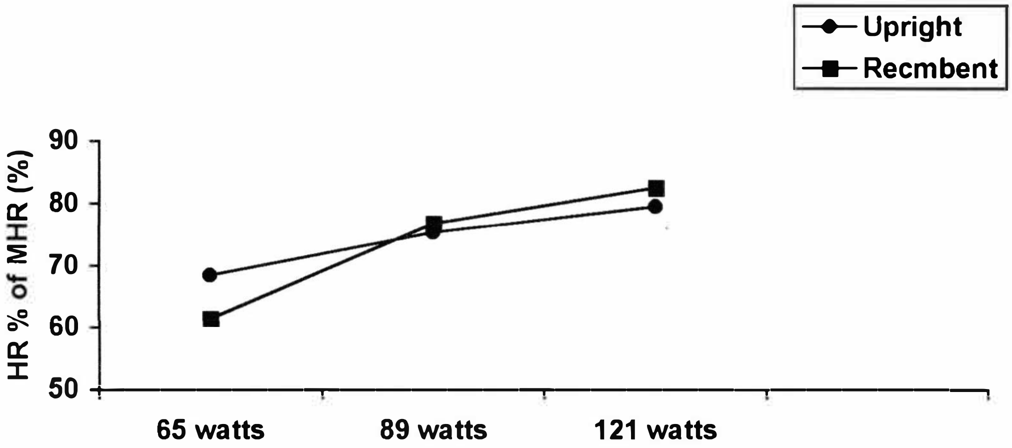

Figure 2. Significant Interaction Effect for Resistance by Bike on % max HR

VO_2 as a Percentage of VO_2 Maximum

The means and standard deviations for VO_2 as a percentage of VO_2 maximum are included in Appendix H. The repeated measures ANOVA summary for VO_2 as a percentage of VO_2 maximum is presented in Table 4. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. A significant difference was found for the main effect, rpm, $F(2, 34) = 133.41$, $p<.05$.

2. Since the assumption of sphericity could not be met, the degrees of freedom were adjusted using the Greenhouse-Geisser method. A significant difference existed for the main effect, resistance, $F(1.38, 23.50) = 89.95$, $p<.05$.

Table 3

ANOVA Summary for Relative VO_2

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	482.29	2.00	241.14	125.39	.00
Error (Rpm)	65.39	34.00	1.92		
Res (R)	7937.59	2.00	3968.79	125.20	.00
Error (R)	1077.81	34.00	31.70		
Bike (B)	68.15	1.00	68.15	22.47	.00
Error (B)	51.57	17.00	3.03		
Rpm x R	13.92	4.00	3.48	2.76	.05
Error (Rpm x R)	86.63	68.00	1.26		
Rpm x B	1.47	2.00	.73	.29	.75
Error (Rpm x B)	84.42	34.00	2.54		
R x B	532.85	2.00	266.43	182.39	.00
Error (R x B)	49.67	34.00	1.46		
Rpm x R x B	4.47	4.00	1.12	.68	.61
Error (Rpm x R x B)	112.41	68.00	1.65		

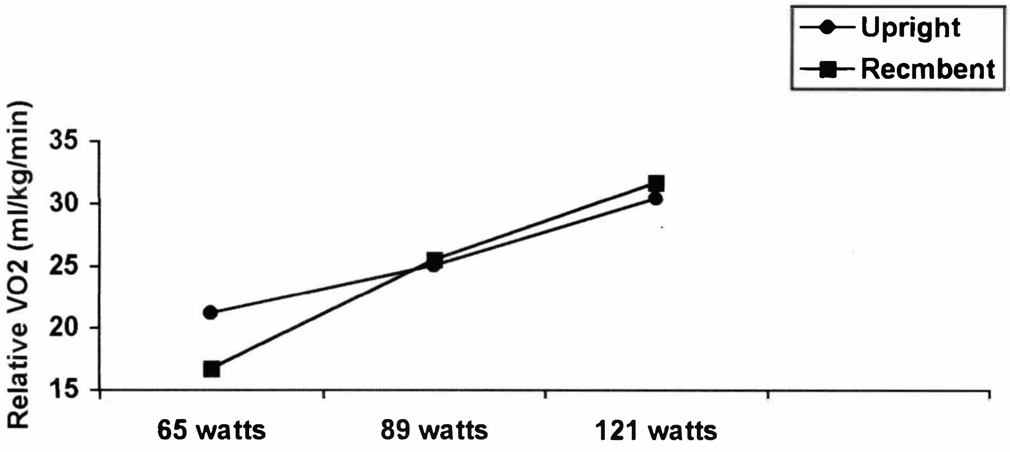

Figure 3. Significant Interaction Effect for Resistance by Bike on Relative VO_2

3. A significant difference was found for the main effect, bike, $F(1, 17) = 24.45$, $p<.05$.

4. No significant difference existed for the first order interaction effect, rpm by resistance, $F(4, 68) = 2.32$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = .63$, $p>.05$.

6. A significant difference existed for the first order interaction effect, resistance by bike, $F(2, 34) = 153.44$, $p<.05$. The interaction effect is depicted in Figure 4.

7. No significant difference was found for the second order interaction effect, resistance by bike by rpm, $F(4, 68) = .765$, $p>.05$.

Table 4

ANOVA Summary for VO_2 as a Percentage of VO_2 Maximum

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	2030.26	2.00	1015.13	133.41	.00
Error (Rpm)	258.70	34.00	7.61		
Res (R)	36393.72	1.38	26328.07	89.95	.00
Error (R)	6877.85	23.50	292.68		
Bike (B)	276.67	1.00	276.67	24.45	.00
Error (B)	192.38	17.00	11.32		
Rpm x R	50.98	4.00	12.75	2.32	.07
Error (Rpm x R)	374.32	68.00	5.51		
Rpm x B	13.06	2.00	6.53	.63	. 54
Error (Rpm x B)	351.93	34.00	10.35		
R x B	2278.96	2.00	1139.48	153.44	.00
Error (R x B)	252.50	34.00	7.43		
Rpm x R x B	20.41	4.00	5.10	.77	.55
Error (Rpm x R x B)	453.46	68.00	6.67		

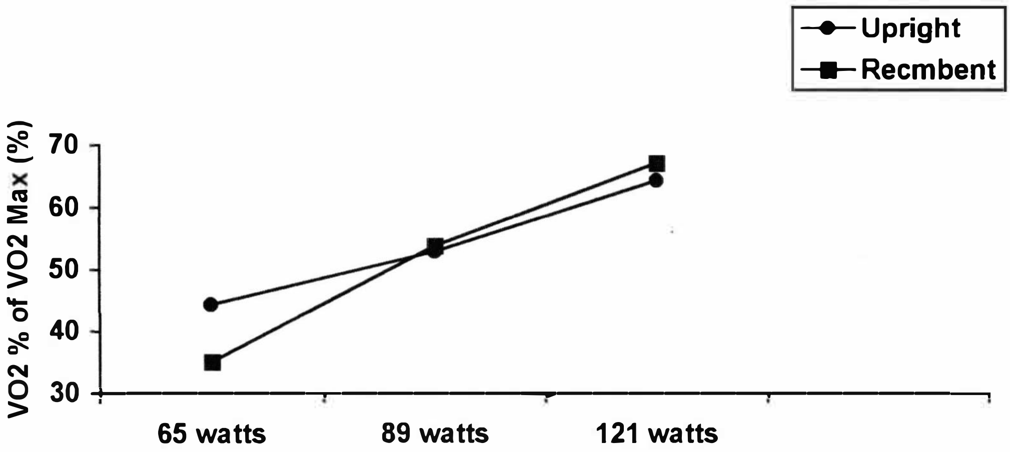

Figure 4. Significant Interaction Effect for Resistance by Bike on % VO_2 Max

Absolute Energy Cost

The means and standard deviations absolute energy cost are included in Appendix I. The repeated measures ANOVA summary for absolute energy cost is presented in Table 5. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. The assumption of sphericity could be met for the main effect, rpm; therefore, the Huynh-Feldt method was used to determine the degrees of freedom. A significant difference was found in the main effect, rpm, $F(1.54, 26.13) = 107.65$, p<05.

2. A significant difference existed for the main effect, resistance, $F(2, 34) = 210.16$, p<.05.

3. A significant difference was found for the main effect, bike, $F(1, 17) = 25.64$, $p<.05$.

4. No significant difference existed for the first order interaction, rpm by resistance, $F(4, 68) = 2.86$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = .402$, $p>.05$.

6. A significant difference existed for the first order interaction effect, resistance by bike, $F(2, 34) = 156.82$, $p<.05$. This interaction effect is represented in Figure 5.

7. No significant difference was found for the second order interaction effect, rpm by resistance by rpm, $F(4, 68) = .788$, $p>.05$.

Rating of Perceived Exertion Legs

The means and standard deviations for rating of perceived exertion (RPE) legs are included in Appendix J. The repeated measures ANOVA summary for RPE legs is presented in Table 6. This analysis consisted of independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. Since the assumption of sphericity could not be met for the main order, rpm, the Greenhouse-Geisser method was used to adjust the degrees of freedom. A significant difference existed for the main effect, rpm, $F(1.31, 22.32) = 4.63$, $p<.05$.

2. A significant difference existed for the main effect, resistance, $F(2, 34) = 48.66$, $p<.05$.

Table 5

ANOVA Summary for Absolute Energy Cost

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	54.07	1.54	35.17	107.65	.00
Error (Rpm)	8.54	26.13	.33		
Res (R)	843.78	2.00	421.89	210.16	.00
Error (R)	68.26	34.00	2.01		
Bike (B)	6.60	1.00	6.60	25.64	.00
Error (B)	4.38	17.00	.26		
Rpm x R	1.86	4.00	.47	2.86	.08
Error (Rpm x R)	11.08	68.00	.16		
Rpm x B	.17	2.00	.00	.40	.67
Error (Rpm x B)	7.18	34.00	.21		
R x B	56.51	2.00	28.26	156.82	.00
Error (R x B)	6.13	34.00	.18		
Rpm x R x B	.66	4.00	.17	.79	.54
Error (Rpm x R x B)	14.20	68.00	.21		

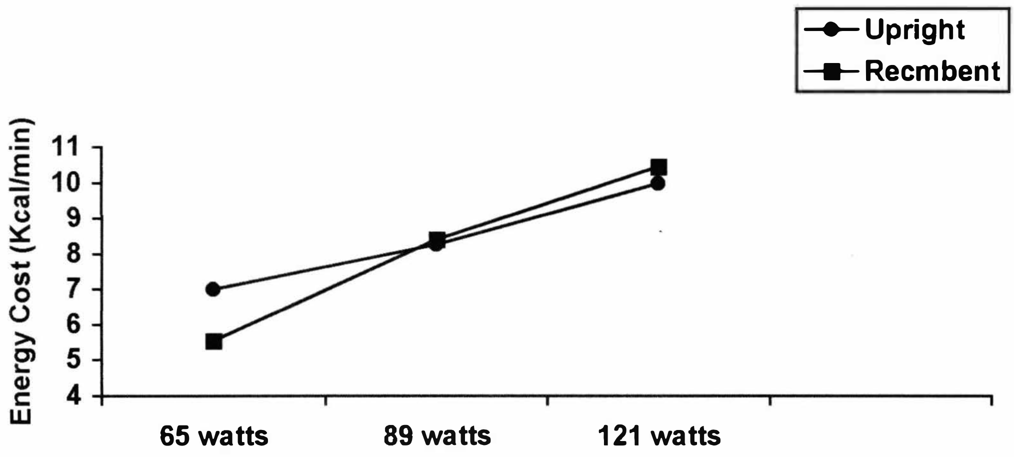

Figure 5. Significant Interaction Effect for Resistance by Bike on Energy Cost

3. A significant difference was found for the main effect, bike, $F(1, 17) = 58.53$, $p<.05$.

4. The Huynh-Feldt method was used to adjust the degrees of freedom since the assumption of sphericity was not met for the first order interaction, rpm by resistance. No significant difference existed for the interaction, rpm x resistance, $F(3.19, 54.29) = .923$, $p>.05$.

5. No significant difference was found for the first order interaction effect, rpm by bike, $F(2, 34) = .348$, $p>.05$.

6. A significant difference existed for the first order interaction effect, resistance by bike, $F(2, 34) = 32.06$, $p<.05$. Figure 6 illustrates the interaction effect.

7. No significant difference was found for the second order interaction effect, rpm by resistance by bike, $F(4, 68) = .591$, $p>.05$.

Table 6

ANOVA Summary for RPE Legs

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	10.67	1.31	8.13	4.63	.03
Error (Rpm)	39.22	22.32	1.76		
Res (R)	1068.32	2.00	534.16	48.66	.00
Error (R)	373.24	34.00	10.98		
Bike (B)	107.93	1.00	107.93	58.53	.00
Error (B)	31.35	17.00	1.84		
Rpm x R	3.92	3.19	1.23	.92	.44
Error (Rpm x R)	72.19	54.29	1.33		
Rpm x B	.75	2.00	.37	.35	.71
Error (Rpm x B)	36.48	34.00	1.07		
R x B	61.14	2.00	30.57	32.06	.00
Error (R x B)	32.42	34.00	.95		
Rpm x R x B	1.66	4.00	.42	.59	.67
Error (Rpm x R x B)	47.78	68.00	.70		

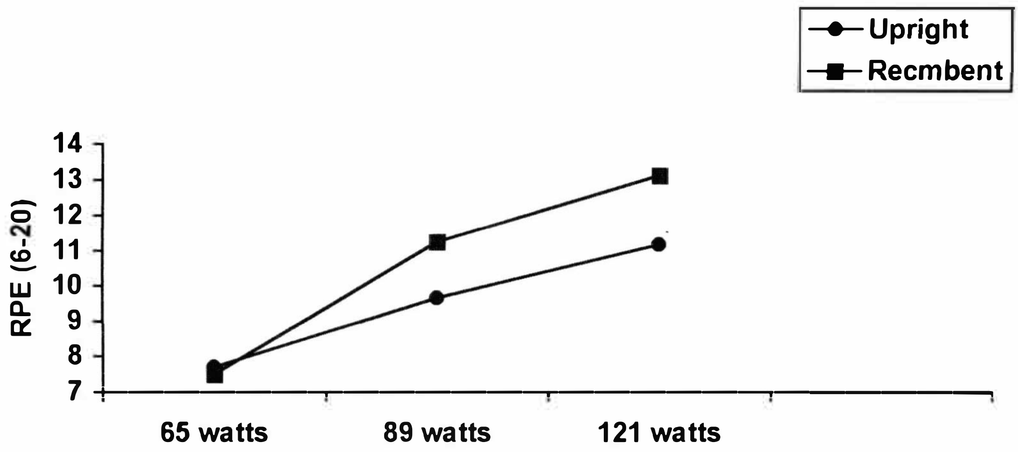

Figure 6. Significant Interaction Effect for Resistance by Bike on RPE Legs

Rating of Perceived Exertion Overall

The means and standard deviations for rating of perceived exertion (RPE) overall are included in Appendix K. The repeated measures ANOVA summary for RPE overall is presented in Table 7. This analysis consisted of the independent variables: (a) rpm (3), (b) resistance (3) and (c) bike (2). The analysis indicated the following:

1. The assumption of sphericity could not be met for the main effect, rpm. The Greenhouse-Geisser method was used to adjust the degrees of freedom. A significant difference existed for the main effect, rpm, $F(1.21, 20.60) = 7.69$, $p<.05$.

2. A significant difference existed for the main effect, resistance, $F(2, 34) = 46.58$, $p<.05$.

Table 7

ANOVA Summary for RPE Overall

Source	*SS*	*df*	*MS*	*F*	*p*
Rpm	10.69	1.21	8.82	7.69	.00
Error (Rpm)	23.64	20.60	1.15		
Res (R)	853.27	2.00	426.63	46.58	.00
Error (R)	311.40	34.00	9.16		
Bike (B)	90.25	1.00	90.25	39.65	.00
Error (B)	38.39	17.00	2.28		
Rpm x R	1.72	3.21	.53	.63	.64
Error (Rpm x R)	46.28	54.62	.85		
Rpm x B	.667	2.00	.33	.34	.71
Error (Rpm x B)	33.22	34.00	.98		
R x B	65.13	2.00	32.57	26.94	.00
Error (R x B)	41.09	34.00	1.21		
Rpm x R x B	.815	4.00	.20	.33	.86
Error (Rpm x R x B)	41.63	68.00	.61		

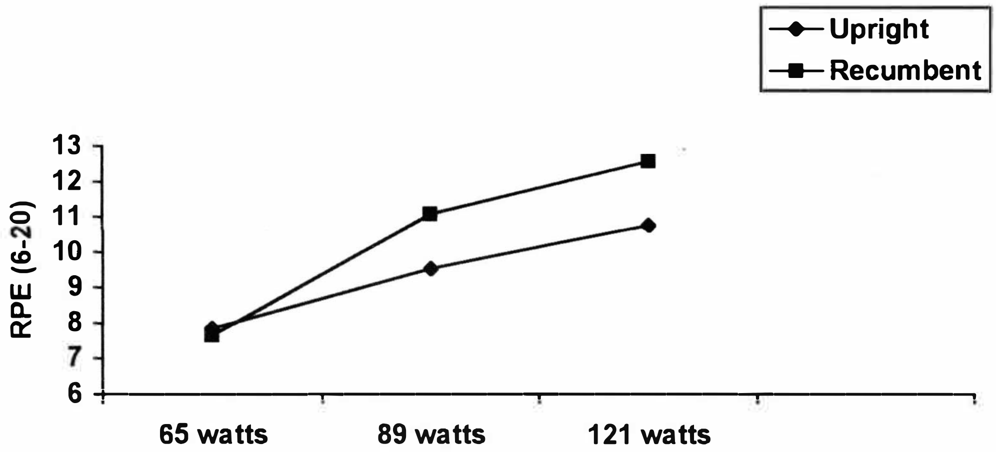

Figure 7. Significant Interaction Effect for Resistance by Bike on RPE Overall

3. A significant difference was found for the main effect, bike, $F(1, 17) = 39.65$, $p<.05$.

4. The Huynh-Feldt method was used to adjust the degrees of freedom for the first order interaction effect rpm by resistance since the assumption of sphericity could not be met. A significant difference was not found for this interaction, $F(3.21, 54.62) = .63$, $p>.05$.

5. No significant difference existed for the first order interaction, rpm by bike, $F(2, 34) = .34$, $p>.05$.

6. A significant difference was found for the first order interaction effect, resistance by bike, $F(2, 34) = 26.94$, $p<.05$. Figure 7 represents this interaction effect.

7. No significant difference was found for the second order interaction effect,

7. No significant difference was found for the second order interaction effect, rpm by resistance by bike, $F(4, 68) = .33$, $p>.05$.

Discussion

The results indicate significant differences in physiological and perceptual responses among various resistances and cycling cadences on the upright and recumbent bicycles. The discussion includes the following topics: (a) physiological variables, (b) perceptual variables, and (c) summary.

Physiological Variables

All physiological variables measured (heart rate, % max HR, relative VO_2, % VO_2 max, and absolute energy cost) increased as pedaling frequency increased. This increase was shown to be significant between 60 rpm and 90 rpm, and 70 rpm and 90 rpm, but not between 60 rpm and 70 rpm. This indicated that small increases in rpm (10) had no significant effect on physiological variables while larger increases in rpm (20 and 30) did have a significant influence. This significant effect can be attributed to the increased demands placed on muscular recruitment to propel the pedal crank at increased pedaling frequencies. Furthermore, at higher pedaling rates, various muscles may be used to stabilize the trunk to eliminate extraneous motion. This additional work will increase oxygen consumption and energy expenditure (Burke, 1986).

The present study's results are similar to findings of other bicycle research.

Nickelberry, et al. (1996) found a linear relationship between R values and cycling cadence. An increase in cycling cadence from 50 rpm to 80 rpm increased R values from .93 to .96. Likewise, a linear relationship was established between oxygen consumption and cycling cadence. Reported mean VO_2 values increased from 3.08 $l \cdot min^{-1}$ to 3.14 $l \cdot min^{-1}$ when pedaling frequency increased from 50 rpm to 80 rpm.

The research hypotheses for physiological factors were partially supported. Physiological factors were lower on the recumbent bicycle than the upright bicycle at 65 watts, thus refuting the research hypothesis. Conversely, physiological factors were greater on the recumbent bicycle at 89 watts and 121 watts.

A significant first order interaction effect occurred for resistance by bike for all physiological variables. The rate of increase of physiological variables between bicycles is different between 65 watts and 89 watts than between 89 watts and 121 watts. The greatest increase for all physiological variables occurred on the recumbent bicycle between 65 watts and 89 watts. The increase in all physiological variables between 89 watts and 121 watts on both bicycles is similar. The large rate of increase found on the recumbent bicycle between 65 watts and 89 watts could be associated with rider inexperience and inefficient economy of movement leading to increased physiological responses at the higher workloads.

Perceptual Variables

The perceptual variables (RPE legs and RPE overall) increased as pedaling frequency increased. This increase was found to be significant between 60 rpm and

70 rpm, and 70 rpm and 90 rpm, but not between 60 rpm and 90 rpm. These findings indicated that for perceptual variables, slight to moderate increases in rpm (10 to 20) had a significant effect; whereas, larger increases in rpm (30) did not have a significant impact. This finding supports research by Lollgen, et al. suggesting cyclists preferred a higher pedaling cadence. Since a low rpm requires a higher resistance to create a selected workload, the higher resistances could affect a person's perception of the exercise difficulty.

As with physiological variables, a significant first order interaction effect occurred for perceptual variables for resistance by bike. Likewise, the research hypotheses for perceptual variables were partially supported. At 65 watts, subjects' perception of exertion was quite similar. At 89 watts and 121 watts, the perception of exertion is greater for the recumbent bicycle. It was surmised that subjects' unfamiliarity with cycling on a recumbent bike, particularly at higher workloads contributed to greater RPE values for legs and overall.

Summary

In this study, increasing the cycling cadence caused significant increases in physiological and perceptual variables. It is thought that increased pedaling frequencies place increased demands on muscular recruitment to propel the pedal crank (Cafarelli, 1977). Moreover, at higher pedaling rates, various muscles may be used to stabilize the trunk to eliminate extraneous motion causing increased oxygen consumption and energy expenditure.

Additionally, a significant first order interaction effect occurred for all physiological and perceptual responses for resistance by bike. At 65 watts, the measured variables were greater for the upright bicycle. At 89 watts and 121 watts, physiological and perceptual variables were greater on the recumbent bicycles. This significant interaction effect could be attributed to rider inexperience on the recumbent bicycle as well as mechanical inefficiencies leading to increased physiological responses and perceptions of exertion.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this study was to compare physiological and perceptual responses to riding at three different cadences and three different resistances on a stationary upright and stationary recumbent bicycle. The research is discussed under the following headings: (a) summary, (b) findings, (e) conclusion, and (d) recommendations.

Summary

This study investigated the effects of riding at three different cadences and three different resistances on a stationary upright and stationary recumbent bicycle on the following physiological and perceptual factors: (a) heart rate, (b) %max HR, (c) relative VO_2, (d) % VO_2 max, (e) absolute energy cost, (f) RPE legs, and (g) RPE overall. Eighteen subjects, 11 females and 7 males, completed 18 experimental conditions in random order: (1) 60 rpm, 65 watts, upright, (2) 60 rpm, 65 watts, recumbent, (3) 60 rpm, 89 watts, upright, (4) 60 rpm, 89 watts, recumbent, (5) 60 rpm, 121 watts, upright, (6) 60 rpm, 121 watts, recumbent, (7) 70 rpm, 65 watts, upright, (8) 70 rpm, 65 watts, recumbent, (9) 70 rpm, 89 watts, upright, (10) 70 rpm, 89 watts, recumbent, (11) 70 rpm, 121 watts, upright, (12) 70 rpm, 121 watts, recumbent, (13) 90 rpm, 65 watts, upright, (14) 90 rpm, 65 watts, recumbent, (15) 90 rpm, 89 watts, upright, (16) 90 rpm, 89 watts, recumbent, (17) 90 rpm, 121 watts, upright, and (18) 90 rpm, 121 watts, recumbent.

HR was measured using a standard limb lead EKG during the maximal treadmill testing. Relative VO2 and R values were measured using a Sensormedics metabolic cart. Subjects performed each of the experimental conditions on a LifeCycle® 9500 upright and LifeCycle® 9500R recumbent bicycle in random order for five minutes. During the final minute, HR, relative VO2, and R values were sampled every 20 seconds and the data collected was averaged. RPE values for legs and overall were also recorded during the final minute of riding. Percentage of max HR and % VO_2 max were calculated by dividing the mean values for each condition by the subject's estimated maximum HR and VO_2 max, respectively and multiplying by 100. Absolute energy cost was determined by multiplying the average R value for each condition by 5 kcal.

A three-way repeated measures ANOVA (cadence x resistance x bike) was calculated for each of the dependent variables. All statistical hypotheses were tested at the .05 significance level. When sphericity was not assumed, the Huynh-Feldt method was used to adjust the degrees of freedom if $E > .75$. The Greenhouse-Geiser method was used to adjust the degrees of freedom if $E \leq .75$. A pairwise comparison, Least Significant Difference, was used to determine significance of the differences among the means of each dependent variable.

Findings

The research hypotheses for physiological factors were not all supported. Physiological factors were lower on the recumbent bicycle than the upright bicycle at the lowest resistance (65 watts), thus refuting the research hypothesis. However, physiological factors were greater on the recumbent bicycle than the upright bicycle at the middle (89 watts) and highest (121 watts) resistances.

For HR, the ANOVA analysis found significant differences for rpm, $F(1.58, 26.90) = 49.81$, $p = .00$. Because the assumption of sphericity could not be assumed, the Huynh-Feldt method was used to adjust the degrees of freedom. Since the assumption of sphericity could not be met for resistance by bike, the degrees of freedom were adjusted using the Greenhouse-Geisser method. A significant interaction effect was found for resistance by bike $F(1.30,22.11) = 110.33$, $p = .00$. No other significant interaction effects were found.

Similar to HR, the ANOVA analysis for % max HR showed significant differences between rpm. Since the assumption of sphericity could not be met for rpm, the Huynh-Feldt method was used to adjust the degrees of freedom. A significant difference was found for rpm, $F(1.73, 29.44) = 57.96$, $p = .00$.

A significant first order interaction effect was found for resistance by bike, $F(1.37, 23.32) = 110.84$, $p = .000$. The Greenhouse-Geisser method was used to adjust the degrees of freedom. No other significant interaction effects existed.

The ANOVA analysis revealed a significant difference in relative VO_2 for rpm, $F(2, 34) = 125.39$, $p = .00$. A significant first order interaction effect existed for resistance by bike, $F(2, 34) = 182.39$, $p = .00$. The ANOVA analysis did not show any other interaction effects.

For % VO_2 max, the ANOVA analysis showed significant differences for rpm, $F(2., 34) = 133.41$, $p = .000$.

The ANOVA analysis showed a significant first order interaction effect for resistance by bike, $F(2, 34) = 153.44$, $p = .000$. No other significant interaction effects existed.

For absolute energy cost, the ANOVA analysis showed significant differences for rpm, $F(1.54, 26.13) = 107.65$, $p = .000$. The assumption of sphericity could not be assumed for rpm; therefore, the Huynh-Feldt method was used to determine the degrees of freedom.

A significant difference existed for the first order interaction effect for resistance by bike, $F(2, 34) = 156.82$, $p = .000$. The ANOVA did not reveal any other significant interaction effects.

For perceptual variables, most of the research hypotheses were supported. The ANOVA for RPE for legs showed significant differences for rpm, $F(1.31, 22.32) = 4.63$. Because the assumption of sphericity could not be met for rpm, the Greenhouse-Geisser method was used to adjust the degrees of freedom.

The ANOVA revealed a significant first order interaction effect occurred between resistance and bike, $F(2, 34) = 32.06$, $p = .000$. No other significant interaction effects were found.

For RPE overall, the ANOVA analysis showed significant differences for rpm, $F(1.21, 20.60) = 7.69$, $p = .008$. The Greenhouse-Geisser method was used to adjust the degrees of freedom for rpm since the assumption of sphericity could not be assumed.

A significant first order interaction effect was found for resistance by bike, $F(2, 34) = 26.94$, $p = .000$. No other significant first order interaction effects occurred.

Conclusion

From the results of this study, it was concluded that the upright bicycle generated greater physiological demands than the recumbent bicycle at 65 watts. However, at 89 watts and 121 watts the recumbent bicycle yielded greater physiological demands than the upright bicycle.

The same results were found related to perceptual responses. At 65 watts, the upright bicycle generated greater perceptual demands than the recumbent. It was concluded that perceived exertion for the legs and overall body was greater on the recumbent bicycle than the upright bicycle at 89 watts and 121 watts. While this research showed a difference in physiological and perceptual responses between the bicycles, further research would be recommended to conclusively compare responses between a stationary upright and recumbent bicycle.

Recommendations

The following are recommendations for future research regarding comparing stationary upright and recumbent bicycles:

1. Measure electromyography activity of lower body muscles using the same exercise conditions as this study.

2. Conduct research again using the same exercise conditions after subjects have trained for a specified period of time on both bicycles.

3. Compare physiological and perceptual responses at cadences and resistances different than those used in this study.

4. Measure and compare blood lactate levels between the two bicycles using the same exercise conditions.

5. Conduct research again using the same exercise conditions and a larger sample size.

Appendix A

Subject Recruitment Script

Subject Recruitment Script

Amy Geib is in need of volunteers to participate in a research project she is conducting for her Master's thesis titled *Comparison of Physiological Factors Between Two Different Bicycles*. The study will involve subjects between 18-35 years of age who are "low risk" according to the American College of Sports Medicine's risk classification. Volunteers will complete a paper/pencil health risk appraisal form to qualify to participate in this study. Participation in this study involves all of the following:

1. Completing two 45-minute sessions to test VO_2 max values.
2. Riding a stationary upright and recumbent bicycle at three different cadences (60, 70 and 90 revolutions per minute) at low, medium, and medium high workload settings until reaching a steady state. Participation involves three 60-minute sessions.

You have the option to voluntarily terminate your involvement in the study for any reason. Your participation during this study will not have any effect on your status as a student at Western Michigan University. All test information will be kept confidential. If your are between 18-35 years of age, exercise 2-3 times per week in any aerobic capacity (eg: cycling, running, swimming, etc.), and are interested in getting more information about volunteering for the study, please contact Amy Geib at 616-321-7522.

Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522	Amy Geib at 616-321-7522

Appendix B

Consent Form

Western Michigan University
H. S. I. R. B.
Approved for use for one year from this date:

SEP 07 2001

x Mary Lagerwey
HSIRB Chair

Western Michigan University
Department of Health, Physical Education, and Recreation
Principal Investigators: Drs. Mary Dawson, Tim Michael, and Roger Zabik
Student Investigator: Amy Geib

I have been invited to participate in a research project that will study the physiological effect of exercise using a recumbent and upright stationary bicycle. The research will describe the effects riding a stationary upright and recumbent bicycle at various levels of intensity and cadence have on physiological responses and perceived exertion. I will exercise on one stationary Schwinn 120 upright bicycle and one stationary Schwinn 220 recumbent bicycle. The research project in which I am involved is for Amy Geib's Master's thesis and will be conducted in the Exercise Physiology and Biomechanics Laboratory in the Department of Health, Physical Education and Recreation in the Student Recreation Building at Western Michigan University.

My consent to participate in this project indicates that I will be asked to attend two, 45-minute sessions. I will meet the researchers in the Student Recreation Center, Rooms 1050-60, Western Michigan University. These sessions will begin with a 10-15 minute period in which I will be allowed to warm up using my personal pre-exercise workout. During each of the two sessions I will be administered a VO_2 max (maximum aerobic capacity) test that measures my cardiopulmonary (heart and lungs) limits. For this test, I will run on a treadmill with the speed and uphill grade increasing until I choose to stop or until I reach my maximum VO_2 capacity.

My consent to participate in this project indicates I will be asked to attend three, 60-minute sessions. I will meet the researchers in the Student Recreation Center, Rooms 1050-60, Western Michigan University. These sessions will begin with a 10-15 minute period in which I will be allowed to warm up using my personal pre-exercise workout. During each of the three sessions I will complete one of the following conditions on a Schwinn 120 stationary upright bicycle and a Schwinn 220 stationary recumbent bicycle: (1) pedal at a rate of 60 revolutions per minute, (2) pedal at a rate of 70 revolutions per minute, and (3) pedal at rate of 90 revolutions per minute. During each session, heart rate will be monitored continuously and my blood pressure will be checked every 2 minutes . During each session, I will exercise in the manner described above for a 5-6 minute period at a prescribed resistance level. I will then stop and rest until my heart rate is below 100 bpm. After resting, I will repeat this procedure for two different resistance levels.

The current testing may be of no benefit to me. Knowledge of how the body reacts to recumbent and upright stationary Schwinn bicycles may help fitness specialists decipher which bicycles are best suited for their clients and aid the company in design changes in future models of Schwinn bicycles.

As in all research, there may be unforeseen risks to the participant. The risks to the research participant in this study include risks taken in any moderate fitness program for normal healthy individuals that utilize a recumbent or stationary upright bicycle. At any time, the researchers may terminate the test in following termination criteria set forth by the American College of Sports Medicine (ACSM). Since these bicycles do not involve impact forces the likely risk is fatigue and sore muscles. A person trained in first aid and CPR will be present during the exercise sessions. If an emergency arises, appropriate immediate care will be provided and I will be referred to the Sindecuse Health Center. No compensation or treatment will be made available to me except as otherwise specified in this consent form.

All information concerning my participation is confidential. This means that my name will not appear in any document related to this study. The forms will be coded. Dr. Dawson will keep a separate master list with the names of all participants and their code numbers. Neither my name nor any identifying information will appear in any document related to this study. Once the data are collected and analyzed, the master list will be destroyed. The consent and data forms, and a disk copy of the electronic generated data will be retained for a minimum of three years in a locked file in the principal investigator's laboratory. A second disk copy of the electronic data will be stored by Amy Geib for a minimum of three years.

I may refuse to participate or stop at any time during the study without any effect on my grades or relationship with Western Michigan University. If I have any questions or concerns about this study, I may contact Dr. Mary Dawson at (616) 387-2546 or Amy Geib at (616) 321-7522. I may also contact the Chair of Human Subjects Review Board at (616) 387-8293 or the Vice President for Research at (616) 387-8928 with any concern that I have.

My signature below indicates that I am aware of the purpose and requirements of the study and that I agree to participate.

This consent document has been approved for 1 year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right hand corner or all pages of this consent form. Subjects should not sign this if the corners do not show a stamped date and signature.

Signature of Participant ________________ Date ________________

Signature of Investigator Obtaining Consent ________________ Date ________________

Appendix C

Par Q

SUBJECT SCREENING FORM

Physical Activity Readiness Questionnaire

Yes	No		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered YES to one or more questions, vigorous exercise or exercise testing should be postponed. Medical clearance from your physician is necessary.

American College of Sports Medicine, 2000, Par-Q & You

Appendix D

Human Subjects Institutional Review Board

Letter of Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-5456
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: September 7, 2001

To: Mary Dawson, Principal Investigator
Tim Michael, Co-Investigator
Roger Zabik, Co-Investigator
Amy Geib, Student Investigator for thesis

From: Mary Lagerwey, Chair Mary Lagerwey

Re: HSIRB Project Number 01-07-14

This letter will serve as confirmation that your research project entitled "Comparison of Physiological Factors Between Two Different Bicycles" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. 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 application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: September 7, 2002

Appendix E

Means and Standard Deviations for

Heart Rate

Means and Standard Deviations for Heart Rate

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	129.44	23.19
		70 rpm	129.22	22.30
		90 rpm	134.72	22.02
	89 watts	60 rpm	142.78	23.76
		70 rpm	143.22	24.79
		90 rpm	148.22	22.64
	121 watts	60 rpm	151.89	26.06
		70 rpm	151.44	25.27
		90 rpm	154.61	22.63
Recumbent	65 watts	60 rpm	114.5	16.22
		70 rpm	115.83	16.17
		90 rpm	122.94	19.24
	89 watts	60 rpm	144.39	24.55
		70 rpm	146.39	24.52
		90 rpm	151.11	24.29
	121 watts	60 rpm	156.78	25.00
		70 rpm	157.22	24.37
		90 rpm	161.22	24.41

Appendix F

Means and Standard Deviations for

Heart Rate as a Percentage of Maximum Heart Rate

Means and Standard Deviations for Heart Rate

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	129.44	23.19
		70 rpm	129.22	22.30
		90 rpm	134.72	22.02
	89 watts	60 rpm	142.78	23.76
		70 rpm	143.22	24.79
		90 rpm	148.22	22.64
	121 watts	60 rpm	151.89	26.06
		70 rpm	151.44	25.27
		90 rpm	154.61	22.63
Recumbent	65 watts	60 rpm	114.5	16.22
		70 rpm	115.83	16.17
		90 rpm	122.94	19.24
	89 watts	60 rpm	144.39	24.55
		70 rpm	146.39	24.52
		90 rpm	151.11	24.29
	121 watts	60 rpm	156.78	25.00
		70 rpm	157.22	24.37
		90 rpm	161.22	24.41

Appendix G

Means and Standard Deviations for

Relative VO_2

Means and Standard Deviations for Relative VO_2

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	20.22	2.56
		70 rpm	20.44	3.60
		90 rpm	23.07	2.94
	89 watts	60 rpm	24.17	3.99
		70 rpm	24.35	3.29
		90 rpm	26.76	3.72
	121 watts	60 rpm	29.78	5.90
		70 rpm	29.54	5.87
		90 rpm	32.02	5.26
Recumbent	65 watts	60 rpm	15.27	2.19
		70 rpm	15.98	2.11
		90 rpm	18.96	2.77
	89 watts	60 rpm	24.44	3.74
		70 rpm	24.77	3.99
		90 rpm	27.36	4.03
	121 watts	60 rpm	31.15	5.59
		70 rpm	31.19	4.93
		90 rpm	32.98	5.55

Appendix H

Means and Standard Deviations for

Relative VO_2 as a Percentage of VO_2 Max

Means and Standard Deviations for Relative VO_2 as a Percentage of VO_2 Max

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	42.48	9.60
		70 rpm	42.79	10.36
		90 rpm	47.89	9.35
	89 watts	60 rpm	51.11	14.09
		70 rpm	51.26	12.41
		90 rpm	56.28	13.54
	121 watts	60 rpm	62.94	18.30
		70 rpm	62.56	18.70
		90 rpm	67.44	17.56
Recumbent	65 watts	60 rpm	32.02	7.44
		70 rpm	33.52	7.57
		90 rpm	39.78	9.29
	89 watts	60 rpm	51.54	13.29
		70 rpm	52.30	14.01
		90 rpm	57.71	14.49
	121 watts	60 rpm	65.76	18.00
		70 rpm	65.77	16.96
		90 rpm	69.71	19.05

Appendix I

Means and Standard Deviations for

Absolute Energy Cost

Means and Standard Deviations for Absolute Energy Cost

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	6.68	.82
		70 rpm	6.67	1.05
		90 rpm	7.65	1.20
	89 watts	60 rpm	7.95	.98
		70 rpm	8.06	.92
		90 rpm	8.81	.92
	121 watts	60 rpm	9.76	.89
		70 rpm	9.71	.97
		90 rpm	10.52	.95
Recumbent	65 watts	60 rpm	5.05	.71
		70 rpm	5.30	.63
		90 rpm	6.30	.93
	89 watts	60 rpm	8.04	.72
		70 rpm	8.14	.85
		90 rpm	9.01	.90
	121 watts	60 rpm	10.26	.91
		70 rpm	10.28	.88
		90 rpm	10.84	.83

Appendix J

Means and Standard Deviations for

Rating of Perceived Exertion Legs

Means and Standard Deviations for RPE Legs

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	7.56	.86
		70 rpm	7.67	.77
		90 rpm	8.06	1.39
	89 watts	60 rpm	9.94	2.10
		70 rpm	9.17	1.72
		90 rpm	9.89	2.00
	121 watts	60 rpm	11.28	2.30
		70 rpm	11.00	2.22
		90 rpm	11.22	1.66
Recumbent	65 watts	60 rpm	7.56	.86
		70 rpm	7.56	.98
		90 rpm	8.00	1.46
	89 watts	60 rpm	11.11	2.05
		70 rpm	11.00	1.91
		90 rpm	11.61	2.30
	121 watts	60 rpm	13.17	3.00
		70 rpm	12.94	2.90
		90 rpm	13.22	1.99

Appendix K

Means and Standard Deviations for

Rating of Perceived Exertion Overall

Means and Standard Deviations for RPE Overall

Bike	Resistance	RPM	Mean	Standard Deviation
Upright	65 watts	60 rpm	7.72	1.07
		70 rpm	7.72	.75
		90 rpm	8.11	1.50
	89 watts	60 rpm	9.67	2.00
		70 rpm	9.17	1.50
		90 rpm	9.72	1.90
	121 watts	60 rpm	10.94	2.50
		70 rpm	10.56	2.09
		90 rpm	10.78	1.63
Recumbent	65 watts	60 rpm	7.56	.86
		70 rpm	7.50	.86
		90 rpm	7.89	1.18
	89 watts	60 rpm	11.00	2.03
		70 rpm	10.83	1.98
		90 rpm	11.39	1.94
	121 watts	60 rpm	12.61	2.68
		70 rpm	12.28	2.93
		90 rpm	12.83	2.23

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