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George Hajiefremides

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**A COMPARISON BETWEEN STATIONARY AND MOVING HANDLEBARS
DURING FORWARD AND BACKWARD PEDALING AT VARIOUS
RESISTANCES ON AN ELLIPTICAL TRAINER**

by

George Hajiefremides

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health, Physical Education,
and Recreation

Western Michigan University
Kalamazoo, Michigan
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George Hajiefremides

A COMPARISON BETWEEN STATIONARY AND MOVING HANDLEBARS DURING FORWARD AND BACKWARD PEDALING AT VARIOUS RESISTANCES ON AN ELLIPTICAL TRAINER

George Hajiefremides, M.A.

Western Michigan University, 2002

The study compared the effects of moving handlebars versus stationary handlebars during forward or backward pedaling on the Precor® EFX™ 556 elliptical trainer. The variables measured were: heart rate, heart rate as a percent of maximum heart rate, relative VO_2 , relative VO_2 as a percent of VO_2 max, absolute CE, relative CE, RPE for arms, RPE for chest, RPE for legs and RPE for overall body. The 12 subjects completed four conditions – arm use with FR pedaling, no arm use with FR pedaling, arm use with BK pedaling, and no arm use with BK pedaling, at three resistance levels – 4, 8, 12, and pedaled at 100 strides per minute. ANOVA analyses indicated that increased resistance produced greater physiological and RPE values. However, ANOVA analyses revealed that the use of moving handlebars produced similar physiological and perceptual responses when compared to stationary handlebars during forward or backward pedaling. Although the EFX™ 556 elliptical trainer allowed variety of workout combinations and would be a reliable cardiovascular exercise machine for improving and maintaining aerobic fitness, it did not provide a total body exercise.

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CHAPTER I

INTRODUCTION

The first elliptical trainer was introduced in 1995 by Precor USA and was designed to provide an effective low-impact cardiovascular exercise. The machine involves an elliptical-shaped pedaling motion, which simulates a cross between upright stationary cycling, stair climbing, walking, and cross-country skiing. Unlike other cardiovascular modalities, the elliptical trainer provides forward (FR) and backward (BK) motion, which adds variety and allows the user to emphasize different muscle groups throughout the workout (Precor, 2000).

Since its introduction, the elliptical trainer has become the most popular cardiovascular machine and the fastest growing fitness trend. The Sporting Goods Manufacturers Association (SGMA) reported that in the year 2000, there were 6.2 million Americans that exercised on an elliptical trainer (SGMA, 2001). This marked an increase of 160% over the 2.4 million users in 1997 (SGMA, 2001). Due to the tremendous increase in use and competitiveness of the industry, innovations such as moving handlebars have been added in order to improve the prototype trainer. The manufacturers state that this addition provides a total body workout, a true cross training exercise, as opposed to a primarily lower body workout provided by machines with only stationary handlebars (Precor, 2000).

Despite the growth in use and the new innovations made by the manufacturers, exercise science research is very limited on the elliptical trainers (Porcari, Foster, & Schneider, 2000). Several studies have compared the elliptical trainer to other popular modalities, such as the treadmill, the cycle ergometer, and the stepper (Porcari, Zedaker, Naser, & Miller, 1998; Pecchia, Evans, Edwards, & Bell, 1999; Wiley, Mercer, Chen, & Bates, 1999). The results showed that the treadmill and the elliptical trainer produced the highest physiological responses, with no significant difference between them, when compared to the other modalities. Two other studies found in the literature compared the differences between FR and BK elliptical pedaling on the elliptical trainer (Kravitz, Wax, Mayo, Daniels, & Charette, 1998; Bakken, 1997). Kravitz et al. (1998) found that BK pedaling produced higher physiological and perceptual responses than FR pedaling at 125 strides per minute (spm). Bakken (1997) found that BK pedaling produced higher heart rate (HR) and ratings of perceived exertion (RPE) than FR pedaling at 100 spm, but no significant differences were noted at 120 spm. Only one study compared the differences between stationary handlebars versus moving handlebars on the elliptical trainer (Crommett, Kravitz, Wongsathikun, & Kemerly, 1999). The results showed no significant difference in oxygen consumption (VO_2), but a higher response in ventilation (VE), HR, and RPE when the subjects used the moving handlebars. Due to the increase of use and the limited amount of research found in the literature it is important to study the differences in the physiological responses between no arm motion versus arm

motion when using stationary and moving handlebars respectively, during FR or backward BK elliptical pedaling.

Statement of the Problem

The present study was conducted to determine if the use of moving handlebars had an effect on the physiological and perceptual responses when combined with FR or BK motion on the elliptical trainer. The results of such a study would provide knowledge to the users, which would assist them in exercising more efficiently. It would also help them understand the physiological differences between the conditions. The results would assist fitness professionals in designing better exercise programs that would meet their clients' individual needs. The findings of such a study would also provide valuable information to engineers of exercise equipment and assist them in creating new innovations in order to improve existing machines, as well as designing new machines.

Purpose of the Study

The purpose of this study was to compare the differences in physiological and perceptual responses between the moving and stationary handlebars during FR or BK pedaling on the Precor® EFX™ 556 elliptical trainer. The physiological variables measured included HR, HR as a percent of maximum HR (% HR max), relative VO_2 , relative VO_2 as a percent of VO_2 max (% VO_2 max), absolute caloric expenditure (CE), and relative CE. To measure perceptual responses, RPE values were assessed

for the arms (RPE/A), chest (RPE/C), legs (RPE/L) and overall body (RPE/O). The four research conditions that were investigated were: (a) arm use with FR pedaling (AF), (b) no arm use with FR pedaling (NF), (c) arm use with BK pedaling (AB), and (d) no arm use with BK pedaling (NB). Each condition was studied at three resistance levels, 4, 8, and 12, with a stride frequency of 100 strides per minute (spm).

Research Hypotheses

The following research hypotheses were tested for this study:

1. There will not be a significant difference in HR and % HR max when using the moving handlebars during FR or BK motion when compared to the stationary handlebars at the three levels of resistance.
2. There will not be a difference in relative VO_2 and % VO_2 max when using the moving handlebars during FR or BK motion when compared to the stationary handlebars at the three levels of resistance.
3. There will not be a difference in absolute CE and relative CE when using the moving handlebars during FR or BK motion when compared to the stationary handlebars at the three levels of resistance.
4. There will not be a difference in RPE/A, RPE/C, RPE/L, and RPE/O when using the moving handlebars during FR or BK motion when compared to the stationary handlebars at the three levels of resistance.

Delimitations

The following delimitations were identified for this study:

1. The subjects that participated in the study were volunteers from Western Michigan University (WMU) who were recruited from Exercise Science and Physical Education classes, and Student Recreation Center (SRC) participants.
2. The subjects were limited to males and females ranging in ages from 18 to 35 years. Subjects were classified, as “low risk” individuals based on the American College of Sports Medicine (ACSM) guidelines, were free of musculo-skeletal injury, and exercised 2-3 times per week (ACSM, 2000).
3. All measurements were conducted in the SRC Building of WMU, Rooms 1050-1060.
4. The study included four conditions, AF, NF, AB, and NB.
5. Subjects performed each condition at three resistance levels, 4, 8, and 12, a total of 12 trials.
6. The stride frequency was 100 spm for all experimental conditions and resistance levels.

Limitations

The following were limitations of the study:

1. The subjects were volunteers and were not randomly selected; therefore the findings of this study may not represent the general population.

2. The subjects performed one 5-minute trial for each condition at three different resistance levels, which accounted for three trials for each condition per session. This could have affected the results because fatigue may have been a factor.

3. The subjects performed only one trial for each experimental condition whereas additional trials may have produced more reliable results.

Assumptions

The following assumptions were made in this study:

1. The subjects followed all instructions and guidelines both prior and during the testing.

2. The subjects performed to the best of their abilities and consistently throughout each experimental trial.

3. The subjects fully understood the RPE scale and stated their levels of perceived exertion accurately.

4. The equipment used to complete this study was valid, reliable, and calibrated precisely.

Definitions

1. *Absolute caloric expenditure* (CE) ($\text{kcal} \cdot \text{min}^{-1}$): The amount of energy needed to perform an exercise in kilocalories (kcal) per minute (Foss & Keteyian, 1998).

2. *Absolute maximal oxygen consumption* (absolute $\text{VO}_2 \text{ max}$) ($\text{L} \cdot \text{min}^{-1}$): The maximal amount of oxygen in liters (L) that can be consumed by the body during exercise (Brooks, Fahey, & White, 1996).

3. *Absolute oxygen consumption* (absolute VO_2) ($\text{L} \cdot \text{min}^{-1}$): The amount of oxygen needed during an activity, measured in liters (L) per minute (Brooks et al.).

4. *Continuous heavy handlebar support*: Supporting the body weight on the arms with elbows locked on the handlebars during exercise (Butts, Dodge, & McAlpine, 1993).

5. *Continuous light handlebar support*: Placing the palms on the handlebars with the fingers extended, and the elbows slightly flexed with no weight supported during exercise (Zeimet, McNeill, Hall, & Moss, 1985).

6. *Continuous very light handlebar support*: Touching the thumb and the first two fingers on the handlebars, elbows slightly flexed, with no weight supported during exercise (Christman, Fish, Bernhard, Smith, & Mitchell, 2000).

7. *Heart rate* (HR): A measure of the cardiac activity usually expressed as number of beats per minute (bpm) (Foss & Keteyian, 1998).

8. *Metabolic equivalent* (MET): The amount of oxygen required per minute during resting. It is approximately 3.5 ml of oxygen consumed per kilogram (kg) of body weight per minute ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) (Foss & Keteyian, 1998).

9. *Moving Handlebars*: Bars that allow the user to include arm activity and upper body exercise in addition to the lower body exercise while on the elliptical

trainer. The moving handlebars encourage good posture and proper technique (Precor, 2000).

10. *No handlebar support*: When the arms are resting at the sides of the body with the elbows flexed at a comfortable position during exercise, and the subjects can only use the handrails to catch their balance when needed (Christman et al., 2000).

11. *Peak oxygen consumption* (VO_2 peak): A measurement of VO_2 during maximal exercise that does not fit the criteria for VO_2 max (Brooks et al.).

12. *Ratings of perceived exertion* (RPE): A valuable and reliable indicator in monitoring an individual's exercise tolerance. Borg's RPE scale rates exercise intensity on a scale of 6 to 20 (ACSM, 2000).

13. *Relative caloric expenditure* (relative CE) ($\text{kcal} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$): The amount of energy needed to perform an exercise per kilogram (kg) of body weight per minute (Foss & Keteyian, 1998).

14. *Relative maximal oxygen consumption* (relative VO_2 max) ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$): The maximal amount of oxygen in milliliters (ml) that can be consumed per minute relative to body mass (Brooks et al.).

15. *Relative oxygen consumption* (relative VO_2) ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$): The amount of oxygen needed during exercise per minute relative to body mass (Brooks et al.).

16. *Respiratory exchange ratio* (R) ($\text{VCO}_2 \cdot \text{VO}_2^{-1}$): The ratio of carbon dioxide (CO_2) produced to oxygen (O_2) consumed during exercise (Foss & Keteyian, 1998).

17. *Stride rate or frequency* (spm): On the elliptical trainer the stride frequency is the total number of revolutions of both foot pedals per minute, measured in strides per minute.

18. *Submaximal Exercise*: The exercise intensity requires less than the VO_2max (60-70%) of the performer (Foss & Keteyian, 1998).

CHAPTER II

REVIEW OF LITERATURE

The elliptical trainers are popular because of the variety of workout combinations they can provide. The options of using the moving handlebars with a combination of FR or BK elliptical leg motion attract the interest of the users. People have been observed using the machines in many different ways. Some users like to use the moving handlebars in order to include arm motion and allow total body exercise, while others like to hold on to the stationary handlebars for support and focus more on their lower body using FR and, or BK leg motion (Christman et al., 2000). Despite the popularity and the increase in use of the elliptical trainers, research is very limited. The differences between arm support when holding the stationary handlebars and arm motion while holding the moving handlebars during FR or BK elliptical exercise are not known. This literature review contains the following sections: (a) physiological responses to acute cardiorespiratory exercise, (b) ratings of perceived exertion and exercise, (c) indirect calorimetry, (d) comparison of the elliptical trainer to various indoor exercise machines, (e) arm support during exercise, (f) arm use during exercise, (g) FR versus BK pedaling on the elliptical trainer.

Physiological Responses to Acute Cardiorespiratory Exercise

The aerobic energy requirements increase substantially during physical activity. This increased oxygen need generates cardiorespiratory and hemodynamic changes in an individual in order to function effectively and support his or her body's requirements. Some of these changes include increased HR, stroke volume (SV), cardiac output, VO_2 , and VE. The extent of these changes, are based on the individual's fitness level as well as the intensity and type of exercise (Foss & Keteyian, 1998).

Heart Rate (HR)

During exercise, HR increases linearly in proportion to exercise intensity. HR begins to level off at maximal effort and near exhaustion, which indicates that the subject is approaching his/her HR max (the highest rate at which the heart can beat). When the rate of work is held constant at a submaximal level, HR increases until it reaches a plateau. This plateau is the steady state HR, and is optimal for meeting the circulatory demands at that specific rate of work. When there is a subsequent increase in intensity, HR increases until it reaches a new steady state usually within one to two minutes (Wilmore & Costill, 1994).

Stroke Volume (SV)

SV is the amount of blood ejected from the left ventricle during heart contraction. SV changes during exercise to allow the heart to work more efficiently

and is a major determinant of cardiorespiratory endurance capacity. Although researchers agree that SV increases with increasing rates of work up to 40-60% of maximal capacity, findings about what happens afterwards differ. Several studies showed a plateau in SV around 50% of VO_2 max, with little or no change as the intensity increases, whereas other studies showed that SV continues to increase beyond that point. Researchers also stated that it is difficult to assess SV at higher working rates and differences between studies could be due to different techniques used to measure SV, and the accuracy of these techniques at various exercise intensities (Wilmore & Costill, 1994).

Cardiac Output

Cardiac output is the amount of blood pumped out by the heart per minute and is the product of HR and stroke volume ($\text{HR} \times \text{SV}$). Cardiac output increases directly with increasing levels of work and intensity. When exercise intensity level is below 40-60% of VO_2 max cardiac output increases due to increase in both, HR and SV. At higher exercise intensities the increase in cardiac output is mainly due to HR increase, since the SV plateaus or increases at a much slower rate. The purpose of the increase in cardiac output is to meet the increased demand of oxygen by the working muscles (Wilmore & Costill, 1994). At rest, 20% of cardiac output is delivered to the muscles, and the remaining is delivered to the visceral organs (gastrointestinal tract, liver, spleen, and kidneys), heart, and brain. However, during exercise the working muscles

receive the greatest proportion of cardiac output. At maximal effort the working muscles receive up to 85-90% of cardiac output (Foss & Keteyian, 1998).

Oxygen Consumption (VO_2)

VO_2 represents the best overall measure of cardiorespiratory function (Foss & Keteyian, 1998). Exercise intensity and VO_2 are directly related, thus expressing the rate of work or exercise intensity in terms of VO_2 is accurate (Wilmore & Costill, 1994). During submaximal exercise the VO_2 increases with intensity until steady state is achieved, then VO_2 plateaus and remains steady. As exercise intensity increases towards maximal effort, VO_2 increases and then starts to level off. This value indicates the VO_2 max. According to the Fick equation, absolute cardiac output equals to absolute VO_2 divided by the arterial-venous oxygen difference (the difference in oxygen content between arterial and mixed venous blood), which represents oxygen utilization. When rearranging this equation the absolute VO_2 equals $\text{HR} \times \text{SV} \times \text{oxygen utilization}$. This specifies that increase in HR will produce an increase in VO_2 during submaximal exercise (Foss & Keteyian, 1998).

Ventilation (VE)

VE increases during exercise in direct proportion to exercise intensity, and parallels VO_2 until the ventilatory point. This point is reached when intensity exceeds 55-70% of one's VO_2 max and the oxygen delivered to the working muscles can no longer support the O_2 requirements of oxidation. Beyond this point VE increases

disproportionately, at a higher rate, as the body tries to clear excess CO₂ (Wilmore & Costill, 1994).

Ratings of Perceived Exertion (RPE) and Exercise

The RPE is an indicator of an individual's tolerance to exercise and the most commonly used RPE scale is Borg's category scale (ACSM, 2000). It was first introduced in the early 1960s and its validity and reliability were tested by a series of studies that were conducted in the 1970s and 1980s. The results showed that the scale is a reliable and valid instrument when measuring perceived exertion. Perceived exertion can be defined as a method to determine the intensity of overall effort, stress, or discomfort that is felt during exercise. Although the scale rates perceived exertion for the overall sensation quality of the body, differentiated ratings have become common and used since the mid-1970s. The researchers use differentiated ratings to isolate upper body sensations from lower body sensations during exercise. Borg's category scale (see Appendix F) rates exercise intensity on a scale of 6 to 20, where six is rest, seven is very very light, 19 is very very hard and 20 is exhaustion (Noble & Robertson, 1996). The RPE measures recorded during graded exercise are highly correlated with HR and work rates. Although different types of exercise can produce similar physiological responses, the RPE values may vary, which means that each exercise type may be perceived differently (ACSM, 2000).

Indirect Calorimetry

As mentioned earlier in this chapter the physiological responses such as HR, respiratory rate, and VO_2 increase during exercise. As a result of these changes the body's metabolism increases, thus producing heat and greater amounts of free energy. Two traditional methods for measuring whole-body metabolism are direct and indirect calorimetry. Direct calorimetry measures the heat production as a result of cellular respiration and cell work and requires the subject to be placed in an air tight chamber. As the body produces heat the chamber's temperature rises and the metabolic rate is determined in joules or kilocalories. This precise method of measuring the metabolic rate in humans requires expensive equipment and is not often used in the exercise science laboratories. More often indirect calorimetry is used. It determines the metabolic rate and energy expenditure by analyzing respiratory gas concentrations and volumes. Gas concentrations and volumes are measured using open circuit spirometry. Respiration gases are directed through a one-way breathing valve into a metabolic cart which measures both O_2 and CO_2 samples. The metabolic cart also calculates the expiratory exchange ratio (R), which is the VO_2 divided by the carbon dioxide produced (VCO_2) (Demarre, Powers, & Lawler, 2001).

Comparison of the Elliptical Trainer to Various Indoor Exercise Machines

The elliptical trainer is the fastest growing fitness trend because it provides a low-impact workout and is a reliable mode of exercise for developing and maintaining aerobic fitness (Porcari et al., 2000). A study that was conducted at the

University of Wisconsin-Lacrosse compared the physiological responses of an elliptical trainer to a treadmill, a cycle ergometer, and a stepper. The subjects were 16 healthy volunteers, eight males and eight females, between the ages of 27 and 54 years. Each subject completed a 20-minute exercise trial at a self-selected pace on each modality. The variables measured were relative VO_2 , HR, absolute CE, RPE, and vertical ground reaction forces (VGRF). The results showed that running on the treadmill, and exercising on the elliptical trainer produced the highest physiological responses. These two modalities produced similar results in HR, relative VO_2 , absolute CE, and RPE. However, the results showed that the elliptical trainer created less than half the VGRF created by the treadmill during running. The results were similar for females and males (Porcari et al., 1998).

Peechia et al. (1999), at Indiana State University compared the elliptical trainer to the treadmill when the subjects exercised at 55% of their VO_2 max. Twelve subjects between the ages of 18 and 40 were randomly assigned two 20-minute exercise sessions (one on the elliptical trainer and one on the treadmill), and the variables measured were HR, relative VO_2 , and RPE. The two modalities produced similar results with no significant differences.

Another study that was conducted at the University of Oregon found analogous results when the researchers compared the peak VO_2 and peak HR values during graded exercise test (GXT) on the elliptical trainer and the treadmill. Thirteen subjects, four females and nine males, completed two GXTs (one on each modality) on two separate days with at least 48 hours between tests. During the treadmill GXT

speed and inclination were increased each stage, while during the elliptical trainer GXT the resistance level was increased. The results showed that there was no significant difference in peak VO_2 and peak HR between the two modalities, and no interaction between the modalities and gender (Wiley et al., 1999).

Arm Support During Exercise

Many exercisers who use aerobic fitness equipment such as treadmills, steppers, step treadmills, and elliptical trainers are often seen using continuous handrail support. When a group of women was interviewed, eight out of ten stated that given a choice, they would prefer to use continuous light handrail support or continuous very light handrail support while exercising (Christman et al., 2000).

Research supports the contention that during aerobic exercise the physiological responses differ depending on the amount of hand support applied (Zeimetz et al., 1985). Research concerning continuous front or side handrail support on the treadmill and continuous side handrail support on the stepper and step treadmill has been conducted. The different conditions of handrail support studied were continuous heavy handrail support, continuous light handrail support, continuous very light handrail support, and no handrail support (Butts et al., 1993; Christman et al., 2000; Howley, Colacino, & Swensen, 1992; Zeimetz et al., 1985). As stated by Brooks, Fahey, & White (1996), work is defined as the product of force (mass x acceleration) acting through a distance. Shifting off weight from the legs to the arms by using the handrail supports may reduce the weight on the legs and feet

and the muscle force generated by the leg muscles in order to perform an exercise (ACSM, 2000). Therefore, an exerciser who uses continuous heavy or continuous light handrail support reduces the work and the aerobic requirements the working muscles have to achieve during submaximal exercise (McConnell, Foster, & Thompson, 1991). Taking this into consideration, researchers found that continuous handrail support allowed the subjects to exercise longer. This supports the theory that unloading the legs through continuous handrail support decreases the fatigue of the exercising muscles (Gardner, Skinner, & Smith, 1991).

A reduction in the aerobic requirements and fatigue levels of exercising muscles would lend support to the idea that continuous handrail support reduces the O_2 requirement and heart rate during submaximal exercise. Using a spring-loaded mechanism to quantify a continuous front handrail support on the treadmill, a reduction of 9-30% in mean relative VO_2 was reported when heavy handrail support was compared to no handrail support, in a sample of 15 healthy men (mean age 24 years) (Zeimetz et al., 1985). In a combined group of 30 men and 11 women (mean age 46 years), when comparing continuous light handrail support versus no handrail support on the treadmill, subjects experienced a reduction of mean VO_2 of 16-18 %, and a reduction of mean HR of 8-10% (McConnell et al., 1991). When very light continuous handrail support was compared to no handrail support in a sample of 45 women (18 to 25 years old), mean VO_2 was reduced by 19%. However, there was no significant percentage change in mean HR (von Duvillard & Pivrotto, 1991).

During submaximal stepper exercise, continuous heavy handrail support reduced both mean VO_2 and mean HR in 5 healthy men (20-33 years old), with a percent reduction of 12% and 5% respectively (Howely et al., 1992). In a later study conducted by Christman et al. (2000) 15 healthy women (mean age 45 years) performed submaximal exercise on a step treadmill. At 33 steps per minute mean VO_2 was reduced by 6% when comparing continuous light handrail support versus no handrail support and 4% during very light handrail support versus no handrail support. Mean HR was reduced by 4.8% during continuous light hand support, and 2.5% during continuous very light support. At 25 steps per minute mean VO_2 was reduced by 7-8% during continuous light and continuous very light handrail conditions. Mean HR was reduced by 4.5% during continuous light and 1.2% during continuous very light handrail support.

Arm Use During Exercise

Butts, Knox, and Foley (1995) compared the physiological responses of normal walking with walking on a dual action treadmill, which incorporates arm exercise. The volunteers were 29 men and 37 women, ranging from 17 to 53 years old. Each volunteer completed six, 5-minute steady-state exercises at 2.0, 3.0, and 4.0 miles per hour (mph) on a 3% inclination with and without arm activity (provided by moving handlebars). The results showed that the use of moving handlebars yielded significantly higher responses in VE, VO_2 , HR, and RPE. Researchers also concluded

that using the handlebars to provide arm activity while walking on a dual action treadmill increased energy cost by 55% when compared to normal walking.

In a later study researchers compared a lower body rowing exercise to a total body rowing exercise, which included arm motion. The subjects were fifteen males (26.7 ± 7.1 years old) and completed four, 5-minute randomized submaximal trials at two different workloads. The variables measured were HR, absolute VO_2 , VE, and R. The results showed that the physiological responses were increased with the use of arm motion during rowing (Mayo, Kravitz, Alvarez, and Honea, 1998).

Naser, Porcari, Maldari, and Zedaker (1998) compared the physiological responses on a treadmill, bicycle, and rowbike. A rowbike is a bicycle with moveable handlebars, which provides arm motion. The subjects were 15 active volunteers (seven males and eight females) between the ages of 24 and 56 years. Each subject completed a 20-minute exercise trial at self-selected exercise intensity on each modality. The variables measured were HR, relative VO_2 , absolute CE, and RPE. The results showed that the rowbike produced higher relative HR, VO_2 , and absolute CE values when compared to bicycle. When compared to treadmill jogging the rowbike produced similar relative VO_2 , and absolute CE, but lower HR values. The RPE values were similar for all three modalities.

Crommett et al. (1999), at the University of Mississippi, compared the differences in HR, relative VO_2 , VE, and RPE during submaximal exercise on an elliptical trainer, a treadmill, and an elliptical trainer with moving handlebars. The subjects were 20 healthy males and females (22.7 ± 4.2 years old) and completed six-

minute randomized trials for each modality. The results showed no significant difference in VO_2 . However, the elliptical trainer with the moving handlebars produced a higher response in HR, VE, and RPE. The researchers believed that these responses were partially due to the arm activity during exercise.

Forward (FR) Versus Backward (BK) Pedaling on the Elliptical Trainer

Kravitz et al. (1998) compared the physiological responses of FR pedaling, BK pedaling, FR pedaling with resistance (RE), FR pedaling with increased speed (SP), and FR pedaling with increased slope (IS) on a Precor EFX elliptical trainer. The subjects were 20 healthy male and female volunteers with a mean age of 19.8 ± 2.3 years. The study included five-minute trials of each condition at 125 and 135 spm for the SP condition. The variables measured were relative HR, VO_2 , VE, absolute CE, and RPE. The results indicated that RE and SP produced significantly greater physiological responses than FR pedaling, BK pedaling, and IS. However, when the FR and BK pedaling were compared the results showed that the BK pedaling produced higher responses than the FR pedaling.

Bakken (1997) compared the physiological responses between FR and BK pedaling on the elliptical trainer at two different stride frequencies, 100 spm and 120 spm. The resistance was set at five out of 10 levels and the grade was set at 10 out of 10 levels. The subjects exercised at each condition until they reached a steady state and the variables measured were HR, VE, relative VO_2 , absolute VO_2 , METS, absolute CE, R, and RPE. At 100 spm the only significant differences noted between

FR and BK pedaling were HR and RPE, where BK pedaling produced higher responses. There was no significant difference for VE, relative VO_2 , absolute VO_2 , METS, R, and absolute CE. At 120 spm the physiological responses were higher when compared to 100 spm, but there was no significant difference between FR and BK pedaling.

The purpose of this study was to compare the physiological and perceptual responses between the moving and stationary handlebars during FR or BK pedaling on an elliptical trainer. The physiological variables measured included HR, % HR max, relative VO_2 , % VO_2 max, absolute and relative CE. To perceptual responses measured included, RPE/A, RPE/C, RPE/L, and RPE/O. The four research conditions that were investigated were: (a) AF, (b) NF, (c) AB, and (d) NB. Each condition was studied at three resistance levels, 4, 8, and 12, with a stride frequency of 100 strides per minute (spm).

CHAPTER III

METHODS AND PROCEDURES

The four research conditions that were investigated were: (a) AF, (b) NF, (c) AB, and (d) NB. Each condition was studied at three resistance levels, 4, 8, and 12, with a stride frequency of 100 strides per minute (spm). The dependent variables included HR, % HR max, relative VO_2 , % VO_2 max, absolute CE, relative CE, RPE/A, RPE/C, RPE/L and RPE/O. The following procedural steps are described in this chapter: selection of subjects, instrumentation, testing procedures, and data analysis.

Selection of Subjects

Approval for conducting this study was given by the WMU Human Subjects Institutional Review Board (HSIRB) (see Appendix A). The subjects were between the ages of 18 and 24 years. They were recruited from Exercise Science classes, Physical Education classes, and SRC participants. A recruitment script was given to the instructors of the aforementioned classes. The script was then read, and those students interested signed their name and provided their phone number at the bottom of the recruitment sheet (Appendix B). A recruitment script was also posted in the SRC Building near the location of the elliptical trainers. The subjects that volunteered to participate in the study were classified as “low risk” based on ACSM guidelines

and exercised at least 2-3 times per week (ACSM, 2000). After HSIRB approval the subjects completed a health history assessment form (Appendix C) and signed an institutionally approved statement of consent (Appendix D). After the initial health screening the subjects were required to participate in two maximal graded exercise tests (GXT), which ensured no cardiovascular conditions were present.

Instrumentation

The EFX™ 556 model, Precor® Inc., Bothel WA, was the elliptical trainer used in this study. It has two pedals that create a low-impact elliptical stride, and a ramp stationed under the pedals that allows a stable and smooth elliptical motion. The ramp is fixed at grade 10 and does not allow a change in the inclination of the grade. The EFX™ 556 model has pre-set levels (1 to 20) of resistance, which applies resistance to the pedals while moving. The EFX™ 556 also features moving handlebars that can be used for arm motion during exercise (Precor, 2000). A Quinton Instruments treadmill model 643, Seattle, WA was used for the two graded exercise tests (GXT).

The Sensormedics Vmax229 LV Lite, Yorba Linda, CA, was the metabolic cart used to measure VO_2 and the CE of the subjects while exercising. It is an automated open circuit spirometry system, which analyses mixed expiratory gases that are collected and transported into the computerized unit through a mouthpiece. For this study the mouthpiece used was the Hans Rudolph, Inc. model 1.375, Kansas City, MO. The Calibration of O_2 and CO_2 analyzers with known concentration of

gases was completed by using a Hans Rudolph, Inc. 3-liter Calibration Syringe, model 5530, Kansas City, MO.

The Marquette Cardiosoft, GE Marquette Medical Systems, Milwaukee, WI and the Graphic Controls 8105 electrodes (4 lead) were used to continuously record the electrocardiogram of the subjects during the two GXT. The HR was monitored through the Polar 61214 Heart Rate watch during experimental trials. The blood pressure of the subjects was measured with the Welch Allyn blood pressure cuff, model Tycos, Arden, NC and an IMCO Caliber Aneroid sphygmomanometer, model 72-130-011, Daytona Beach, FL. The Borg's original scale (see Appendix F) was used for the RPE values.

Design of the Study

The subjects participated in four testing sessions, one for each condition (AF, NF, AB, NB). Each session included three five-minute trials where three levels of resistance (4, 8, and 12) were tested. The order of the conditions and resistance levels were randomly assigned for each subject. The study was a repeated measures design ($2 \times 2 \times 3$) with main effects Arms (with and without arm use), Stride (FR and BK), and Resistance (4, 8, and 12) (see Table 1). The dependent variables measured were HR, % HR max, relative VO_2 , % VO_2 max, absolute CE, relative CE, RPE/A, RPE/C, RPE/L, and RPE/O.

Table 1

Research Design

Arms	Stride	Resistance
With	FR pedaling	4
		8
		12
	BK pedaling	4
		8
		12
Without	FR pedaling	4
		8
		12
	BK pedaling	4
		8
		12

Testing Procedures

Graded Exercise Test

After the initial health screening and the completion of the health history questionnaire the subjects performed two GXTs on the treadmill (see Bruce Protocol,

Appendix E) on two different days with a minimum of 48 hours between the tests.

The test was terminated when the subjects reached volitional fatigue, asked to stop or when any contraindications occurred, such as a drop in systolic blood pressure, moderate to severe chest pain, dizziness, ataxia, etc. (ACSM, 2000). The subjects' electrocardiogram, HR, and relative VO_2 were measured continuously during the test. Blood pressure and overall RPE values were recorded during the second minute of each stage. The Borg's original scale was in plain view at all times. The VO_2 max of the subjects was determined after the completion of the two tests, where the highest value out of the two was used in the data analysis.

Elliptical Trainer Test

The elliptical trainer testing was completed in four testing sessions. In each of the four sessions, subjects were randomly assigned and completed one of the following conditions: (a) AF, (b) NF, (c) AB, and (d) NB. The four conditions were tested at three resistance levels, 4, 8, and 12, which were also randomly assigned. Prior to the testing all subjects warmed-up and stretched for 10 minutes using their personal protocol. During warm-up, the subjects were informed of the condition that was going to be tested. They were instructed to step on the foot pedals of the elliptical trainer, stand at the front of the pedals, and apply a continuous light handrail support on the handlebars. When conditions NF and NB were tested the subjects placed their palms on the stationary handlebars with their fingers extended or lightly wrapped around the bars without supporting any weight with their arms. When conditions AF

and AB were tested the subjects lightly wrap their fingers around the moveable bars, which allowed them to involve arm motion while pedaling. The subjects were required to follow the metronome that was set at 100 bpm and one beat corresponded with one pedaling stride.

The subjects exercised at the randomly selected condition and level of resistance for five minutes. During the third minute of each testing trial RPE/A, RPE/C, RPE/L, AND RPE/O values were recorded. The HR and relative VO_2 were collected during the last minute of each trial (at minute four, minute four and 30 seconds, and minute five) when steady state had been reached. A steady state was determined when the HR measurements were within five beats of each other at fourth and fifth minute.

As mentioned above, three trials, one for each resistance level, were completed during each testing session for each condition. Between the trials the subjects continued to pedal slowly on the elliptical trainer at the lowest resistance level until their HR decreased to 100 bpm or lower. After their HR recovered the resistance was set to the predetermined level and the subjects performed the next trial.

Statistical Analysis

The mean values for HR, relative VO_2 , and RPE were calculated by averaging the results recorded the last minute of each trial. To determine HR and relative VO_2 as % HR max and % VO_2 max, respectively, the subjects' means for HR and relative VO_2 for each experimental condition and resistance level were divided by the HR

max and relative VO_2 max results that were recorded during the GXTs. The absolute CE was calculated by multiplying the absolute VO_2 by five and the relative CE was calculated by dividing the absolute CE by the subject's weight (Foss & Keteyian, 1998).

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS). Standard descriptive statistics were calculated for all variables and, three way repeated measures ANOVA ($2 \times 2 \times 3$) with repeated measures on all factors were conducted to analyze the variables for main effects (Arms, Stride, and Resistance), and interaction effects (Arms \times Stride, Arms \times Resistance, Stride \times Resistance, and Arms \times Stride \times Resistance) to determine the influence of the moving handlebars on the physiological responses at each resistance level, and to determine whether FR or BK motion also influenced these responses. All statistical hypotheses were tested at level of significance 0.05, and where the sphericity assumption was not met a correction was used.

CHAPTER IV

RESULTS

The following results are presented in this chapter: (a) subject demographics, (b) HR and HR as a percent of max HR, (c) relative VO_2 and relative VO_2 as a percent of VO_2 max, (d) absolute and relative CE, (e) RPE/A, RPE/C, RPE/L, and RPE/O.

Subject Demographics

The demographics of the subjects that participated in this study are presented in Table 2.

Table 2

Subject Demographics

	n	Minimum	Maximum	Mean	SD
Age (yrs)	12	18.0	24.0	21.5	1.62
Weight (kg)	12	49.5	104.5	75.2	15.60
Max HR (bpm)	12	154.0	204.0	192.6	13.84
$\text{VO}_{2\text{max}}$ ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	12	39.3	59.0	45.5	5.32

Heart Rate (HR) and HR as a Percent of Maximum HR (% HR max)

Table 3 presents the means and standard errors of the mean (SE) for HR and % HR max for the main effects. The ANOVA summary tables are presented in Appendix G, Tables G₁ and G₂. As seen in the results, there were no significant differences for the Arms and Stride main effects, but there was a significant difference for the main effect of Resistance.

Table 3

Means and SE for HR and % HR max

		HR (bpm)		% HR max	
	n	Mean	SE	Mean	SE
Arms					
With	12	122.81	4.72	63.84	2.22
Without	12	122.33	4.55	63.59	2.10
Stride					
FR	12	120.86	4.77	62.82	2.25
BK	12	124.27	4.65	64.60	2.15

Table 3 – Continued

		HR (bpm)		% HR max	
	n	Mean	SE	Mean	SE
Resistance					
4	12	110.04*	4.04	57.18*	1.82
8	12	118.96	4.44	61.84	2.09
12	12	138.71	5.85	72.11	2.79

Note. *Significantly ($p < .05$) different for all pair wise comparisons.

Relative VO_2 and Relative VO_2 as a Percent of VO_2 max (% VO_2 max)

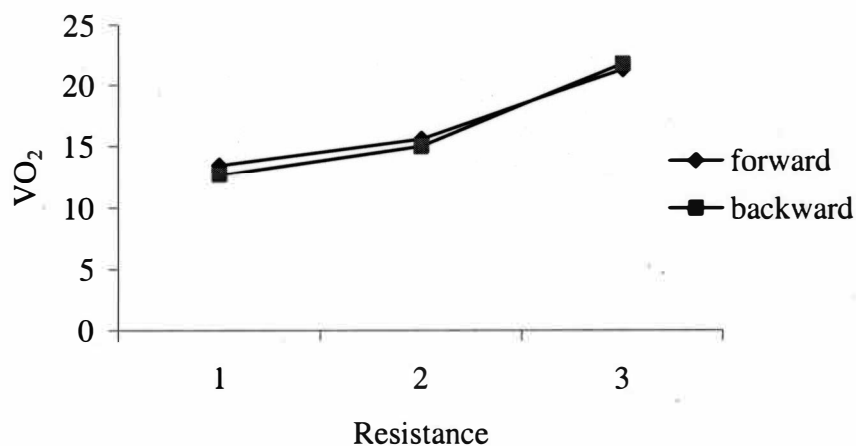
Table 4 presents the means and SE for relative VO_2 and % VO_2 max for the main effects. The ANOVA summary tables are presented in Appendix G, Tables G₃ and G₄. There were no significant differences for the Arms and Stride main effects. There was a significant difference for the main effect Resistance, and a significant first order interaction between Stride \times Resistance for both variables (see Figures 1 and 2).

Table 4

Means and SE for Relative VO₂ and % VO₂ max

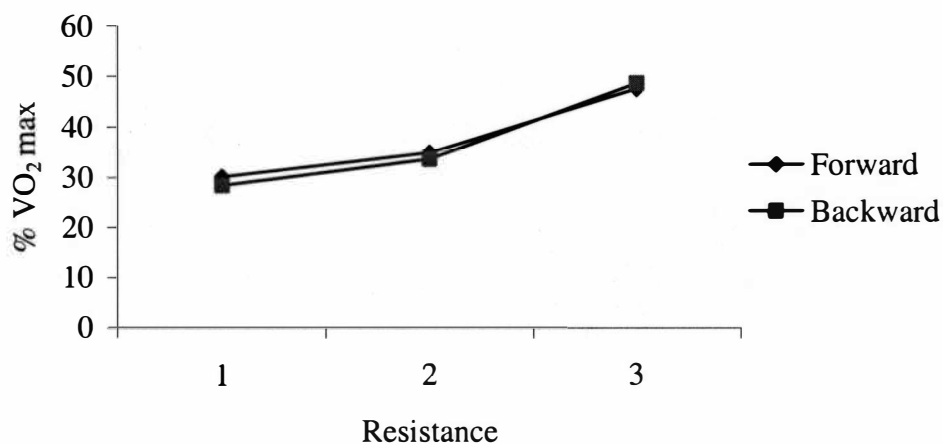
		Relative VO ₂ (ml·kg ⁻¹ ·min ⁻¹)		% VO ₂ max	
	n	Mean	SE	Mean	SE
Arms					
With	12	16.73	.42	34.25	1.46
Without	12	16.69	.47	37.06	1.38
Stride**					
FR	12	16.86	.52	37.47	1.52
BK	12	16.56	.39	36.83	1.35
Resistance**					
4	12	13.15*	.39	29.22*	1.16
8	12	15.40	.37	34.25	1.28
12	12	21.58	.81	47.99	2.24

Note. *Significantly ($p < .05$) different for all pair wise comparisons. **Significant ($p < .05$) interaction between Stride \times Resistance.



Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 1. The Interaction Effect of Stride \times Resistance for VO_2 .



Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 2. The Interaction Effect of Stride \times Resistance for % VO_2 max.

Absolute and Relative Caloric Expenditure (CE)

Table 5 presents the means and SE for absolute and relative CE for each of the main effects. The ANOVA summary tables are presented in Appendix G, Tables G₅ and G₆. As seen in the results, there were no significant differences for the Arms and Stride main effects. There was a significant difference for the main effect of Resistance and a significant first order interaction between Arms \times Stride for both variables (see Figures 3 and 4).

Table 5

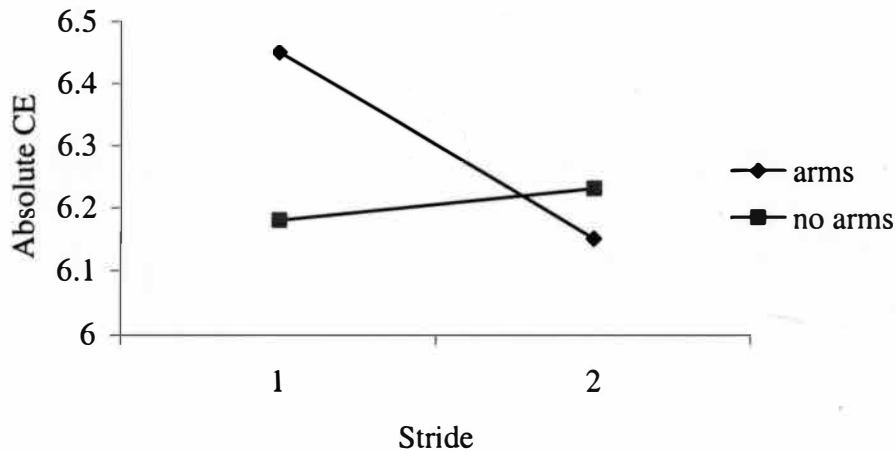
Means and SE for Absolute and Relative CE

		Absolute CE (kcal·min ⁻¹)		Relative CE (kcal·kg ⁻¹ ·min ⁻¹)	
	n	Mean	SE	Mean	SE
Arms**					
With	12	6.30	.37	.08	.002
Without	12	6.21	.35	.08	.003
Stride**					
FR	12	6.32	.39	.08	.003
BK	12	6.19	.32	.08	.002

Table 5 – Continued

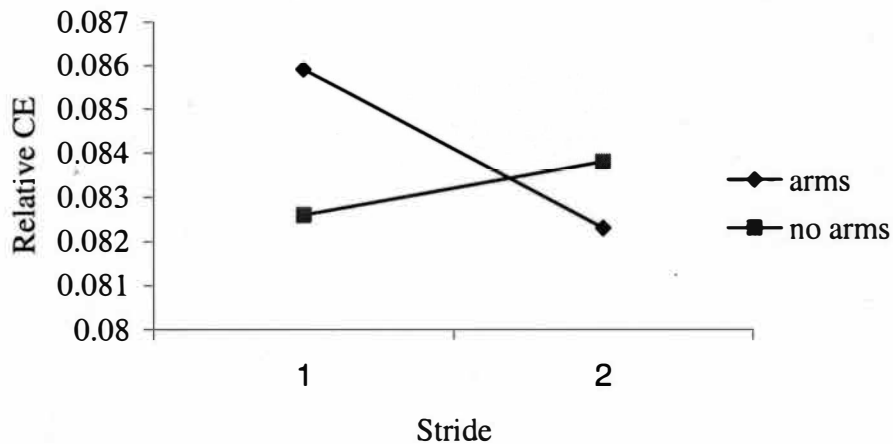
		Absolute CE (kcal·min ⁻¹)		Relative CE (kcal·kg ⁻¹ ·min ⁻¹)	
	n	Mean	SE	Mean	SE
Resistance					
4	12	5.00*	.37	.07*	.002
8	12	5.79	.38	.07	.002
12	12	7.97	.31	.11	.004

Note. *Significantly ($p < .05$) different for all pair wise comparisons. **Significant ($p < .05$) different interaction between Arms \times Stride.



Legend. 1 = FR pedaling, 2 = BK pedaling.

Figure 3. The Interaction Effect of Arms \times Stride for Absolute CE.



Legend. 1 = FR pedaling, 2 = BK pedaling.

Figure 4. The Interaction Effect of Arms \times Stride for Relative CE.

RPE for Arms, Chest, Legs and Overall Body

Table 6 presents the means and SE for RPE/A, RPE/C, RPE/L, and RPE/O for each of the main effects. The ANOVA summary tables are presented in Appendix G, Table G₇, G₈, G₉, and G₁₀. As seen in the results, there was no significant difference for the Stride main effect. There was a significant difference for the main effect of Resistance for all RPE values, and the main effect for Arms for RPE/A and RPE/C. There were significant first order interactions between Arms \times Resistance for RPE/L and RPE/O (see Figures 6 and 8), and between Stride \times Resistance for RPE/C and RPE/L (see Figures 5 and 7).

Table 6

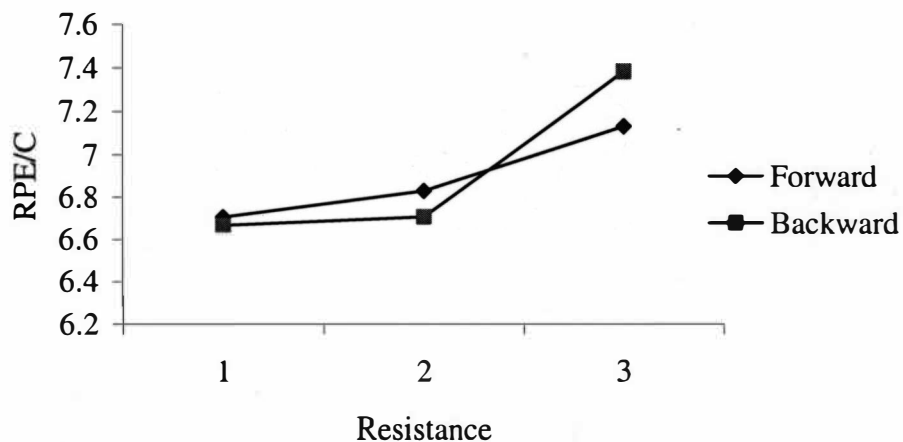
Means and SE for RPE/A, RPE/C, RPE/L, and RPE/O

		RPE/A		RPE/C		RPE/L		RPE/O	
	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Arms [†]									
With	12	7.1**	.06	7.3**	.08	9.2	.25	8.86	.20
Without	12	6.2	.09	6.6	.17	9.4	.25	9.13	.20
Stride ^{††}									
FR	12	6.6	.08	6.9	.11	9.3	.25	8.97	.20
BK	12	6.7	.09	6.9	.17	9.4	.28	9.01	.23
Resistance ^{†, ††}									
4	12	6.5*	.05	6.7*	.08	8.1*	.16	7.9*	.13
8	12	6.6	.08	6.8	.10	9.0	.25	8.7	.20
12	12	6.9	.10	7.3	.19	10.9	.33	10.4	.29

Note. *Significantly ($p < .05$) different for all pair wise comparisons. **Significantly

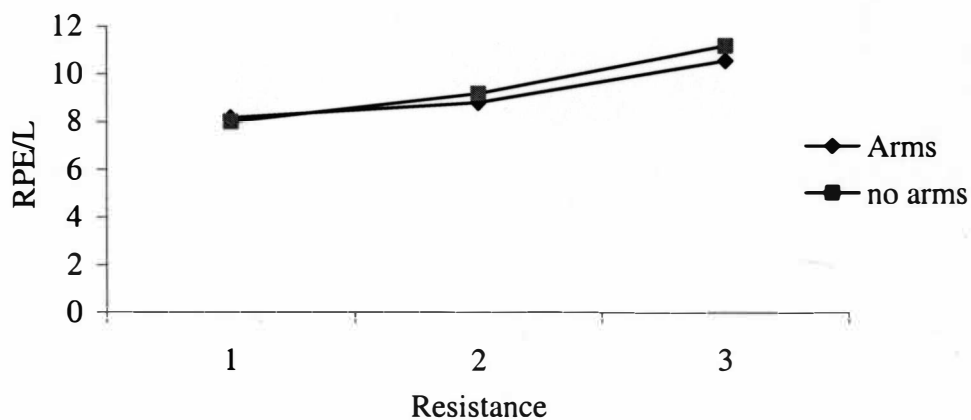
($p < .05$) different for RPE/A and RPE/C. [†]Significantly ($p < .05$) different interaction between Arms \times Resistance for RPE/L and RPE/O.

^{††}Significantly ($p < .05$) different interaction between Stride \times Resistance for RPE/A and RPE/L.



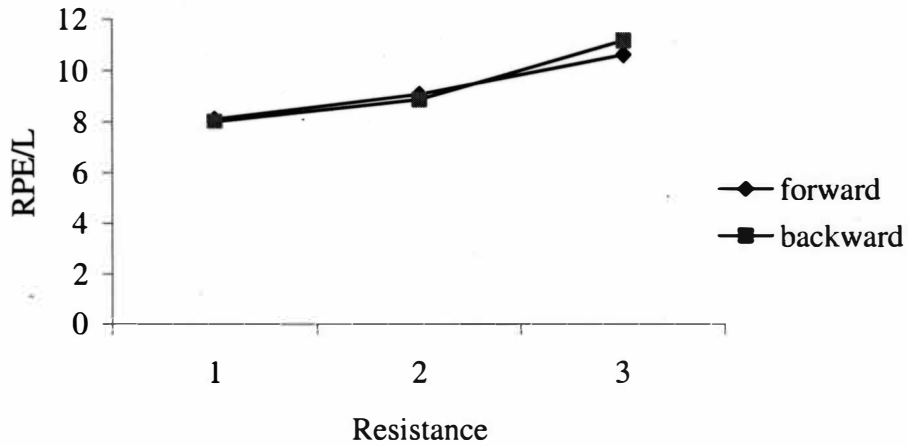
Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 5. The Interaction Effect of Stride \times Resistance for RPE/C.



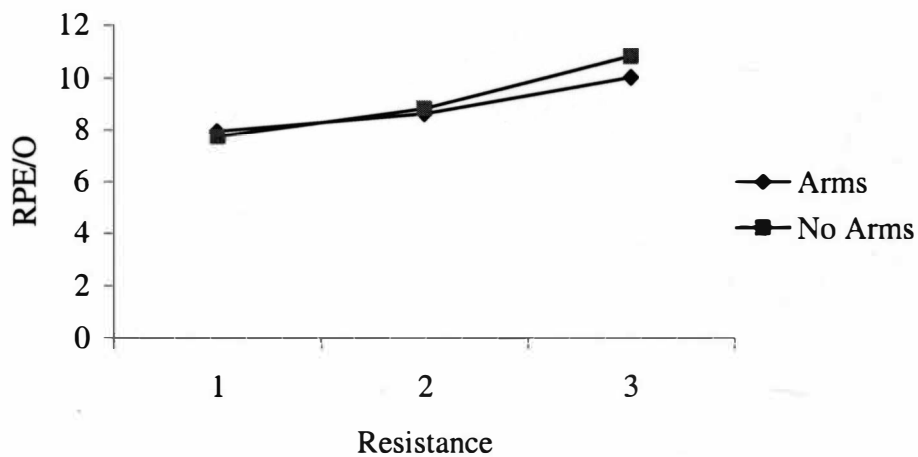
Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 6. The Interaction Effect of Arms \times Resistance for RPE/L.



Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 7. The Interaction Effect of Stride \times Resistance for RPE/L.



Legend. 1 = Resistance level 4, 2 = Resistance level 8, 3 = Resistance level 12.

Figure 8. The Interaction Effect of Stride \times Resistance for RPE/O.

CHAPTER V

DISCUSSION

The present study was conducted to determine whether the use of moving handlebars during FR or BK pedaling on the Precor® EFX™ 556 elliptical trainer had an effect on physiological (HR, VO_2 , and CE) and perceived responses (RPE values) to exercise. Three way repeated measures ANOVA, Arms (2) \times Stride (2) \times Resistance (3) with repeated measures on all factors were conducted. The following areas are discussed in this chapter: (a) main effect for Arms, (b) main effect for Stride, (c) main effect for Resistance, (d) interaction effects, (e) summary of findings, (f) conclusions, and (g) recommendations.

Main Effect for Arms

The two conditions studied for the main effect of Arms were: (a) arm use, where the subjects used the moving handlebars, and (b) no arm use, where the subjects used the stationary handlebars during submaximal exercise on the elliptical trainer while pedaling FR or BK.

Heart Rate (HR) and HR as a Percent of Maximum HR (% HR max)

As seen in Appendix G, Tables G₁ and G₂, the main effect for Arms did not produce a significant difference for HR and % HR max. This indicated that the use of moving handlebars during FR or BK pedaling did not increase the HR responses, which supports the first research hypothesis. However, the results were not consistent with previous studies conducted by Butts et al. (1995), Mayo et al. (1998), Naser et al. (1998), and Crommet et al. (1999), which found that use of moving handlebars increased HR responses on a treadmill, rower, rowbike, and elliptical trainer respectively. Butts et al. (1995), Mayo et al. (1998), and Naser et al. (1998) studied different modalities than the elliptical trainer therefore the inconsistency in findings was most likely due to the different mechanics of the modalities. Although Crommet et al. (1999) used the same modality, the subjects self-selected the exercise intensity.

The use of moving handlebars during FR or BK pedaling on the Precor® EFX™ 556 elliptical trainer did not increase HR response most likely due to the connection of the handlebars to the foot pedals. This caused the handlebars to move with the pedals as a result of the force generated by the user's legs. Since the moving handlebars did not require additional work they provided a passive arm motion, which did not increase the workload and intensity of the exercise. Given that the moving handlebars did not add to the work of exercise, the HR responses are consistent with the literature review, which states that HR increases directly in proportion to exercise intensity (Wilmore & Costill, 1994).

Relative VO₂ and Relative VO₂ as a Percent of VO₂ max (%VO₂ max)

The main effect for Arms did not produce a significant difference for relative VO₂ (Table G₃) and % VO₂ max (Table G₄). This indicated that the use of moving handlebars during FR or BK pedaling did not increase the oxygen demand of the exercise, which supports the second research hypothesis. The results were in agreement with a previous study conducted on the elliptical trainer by Crommett et al. (1999), who found that although use of moving handlebars produced higher HR responses, there was no increase in VO₂ responses. The results were not in agreement with studies conducted by Butts et al. (1995), Mayo et al. (1998), and Naser et al. (1998), which found that use of moving handlebars increased VO₂ responses on a treadmill, rowing exercise, and rowbike respectively. As mentioned earlier, the difference in the results of this study when compared to the studies conducted by Butts et al. (1995), Mayo et al. (1998), and Naser et al. (1998) was most likely due to the different mechanics of the modalities.

The use of moving handlebars on the Precor® EFX™ 556 elliptical trainer did not increase the intensity therefore the VO₂ responses of the exercise were not increased. Given the relationship between HR, VO₂ and exercise intensity this finding is consistent with the published literature (Wilmore & Costill, 1994; Foss & Keteyian, 1998).

Absolute and Relative Caloric Expenditure (CE)

As seen in Tables G₅ and G₆, the main effect for Arms did not produce a significant difference for absolute and relative CE. This indicated that the use of moving handlebars during FR or BK pedaling did not increase the energy cost of the exercise. The results measured support the third research hypothesis. The results were not consistent with previous studies that were conducted on different modalities (Butts et al., 1995; Naser et al., 1998). There was a 55 % increase in energy cost when moving handlebars were used on a treadmill (Butts et al., 1995), and increased CE with the use of moving handlebars on a rowbike (Naser et al., 1998). Crommet et al. (1999) who studied the same modality did not measure CE.

Foss and Keteyian (1998) stated that the VO₂ at rest or during exercise can be expressed as heat equivalents (i.e., kcal) therefore, the measurement of VO₂ serves as an indirect measure of energy expense. Since the moving handlebars did not increase the intensity of the exercise as illustrated by the HR and VO₂ responses, the energy cost of the exercise did not increase either. This supports the results of the present study that showed there was no increase in CE since there was no increase in VO₂.

RPE for the Arms, Chest, Legs and Overall Body

The main effect for Arms produced a significant difference for RPE/A (Table G₇) and RPE/C (Table G₈), but did not produce a significant difference for RPE/L (Table G₉) and RPE/O (Table G₁₀). The use of moving handlebars increased the RPE/A and RPE/C values, but did not change the RPE/L and RPE/O values. These

results do not support the fourth hypothesis, which stated that there would be no significant difference in RPE/A, RPE/C, RPE/L, and RPE/O. The previous studies cited from the literature did not compare RPE values that were differentiated to specific body areas. The RPE/O values were compared with previous studies and were found to be in agreement with the results by Butts et al. (1995), and Crommett et al. (1999). The results however, were in agreement with results found by Naser et al. (1998).

Although the moving handlebars did not increase the exercise intensity, RPE/A and RPE/C values varied as compared to stationary handlebars. This was supported by the literature, which stated that different types of exercise with similar physiological responses might be perceived differently (ACSM, 2000). The results of the present study indicated that exercise with moving handlebars was perceived as harder. Furthermore, the subjects were introduced to the Borg's category scale they were instructed that RPE value of six indicated that they were at rest. Most likely the subjects reported higher RPE/A and RPE/C values when they passively moved their arms. Since the arms were not stationary, resting, the subjects reported higher RPE values.

Main Effect for Stride

The two conditions studied for the main effect of Stride were: (a) FR, and (b) BK pedaling at 100 spm during submaximal exercise on the elliptical trainer while using the stationary or moving handlebars.

Heart Rate (HR) and HR as a Percent of Maximum HR (% HR max)

As seen in Tables G₁ and G₂, the main effect for Stride did not produce a significant difference for HR and % HR max. This indicated that FR and BK pedaling at 100 spm produced similar HR responses, which supports the first research hypothesis. The results of this study were not consistent with previous studies conducted by Kravitz et al. (1998) and Bakken (1997). Kravitz et al. (1998) found that BK pedaling at 125 spm produced higher HR than FR pedaling. Bakken (1997) found that BK pedaling at 100 spm produced higher HR, but BK pedaling at 120 spm produced similar results with no differences when compared to FR pedaling.

The stride frequency and resistance levels were controlled during FR or BK pedaling, therefore, exercise intensity did not change between the two strides. Although electromyography (EMG) was not used and therefore muscle recruitment difference between the two strides is unknown, it is believed that the overall muscle mass used for FR or BK pedaling is the same. The literature supported the results of the present study since HR increases directly in proportion to exercise intensity (Wilmore & Costill, 1994).

Relative VO₂ and Relative VO₂ as a Percent of VO₂ max (%VO₂ max)

The main effect for Stride did not produce a significant difference for relative VO₂ (Table G₃) and % VO₂ max (Table G₄). This indicated that FR and BK pedaling at 100 spm produced similar exercise intensities as determined by the VO₂ data in Table 4, which supports the second research hypothesis. The results were consistent

with previous findings by Bakken (1998), who found no significant difference in VO_2 between FR and BK pedaling at 100 and 120 spm. However, the results found in this study were not consistent with results found by Kravitz et al. (1998), which showed that BK pedaling at 125 spm produced higher relative VO_2 than FR pedaling.

Given that the overall active muscle mass remains the same, and that the intensity does not change during FR or BK pedaling there was not an increase in oxygen need and VO_2 . Therefore, the results of the present study were in agreement with the literature, which stated that VO_2 is directly related to intensity (Wilmore & Costill, 1994; Foss & Keteyian, 1998).

Absolute and Relative Caloric Expenditure (CE)

The results in Tables G₅ and G₆ indicated that the main effect for Stride did not produce a significant difference for absolute and relative CE. Therefore, FR and BK pedaling at 100 spm produce similar energy costs, which supports the third research hypothesis. The results of this study were not consistent with a previous study conducted by Kravitz et al. (1998) that found that BK pedaling at 125 spm produced higher absolute CE than FR pedaling. Bakken (1997) found that BK pedaling at 100 and 120 spm produced similar absolute CE with no differences when compared to FR pedaling, which supports the results of the present study.

FR and BK pedaling produced similar HR and VO_2 values, which resulted in similar absolute and relative CE. The results for this study were supported by the

literature, where it was stated that the energy cost during exercise increases directly with the intensity (Foss & Keteyian, 1998).

RPE for the Arms, Chest, Legs and Overall Body

The main effect for Stride did not produce a significant difference for RPE/A (Table G₇), RPE/C (Table G₈), RPE/L (Table G₉), and RPE/O (Table G₁₀). This would indicate that FR and BK pedaling at 100 spm were perceived similarly, which supports the fourth research hypothesis stated in Chapter I. The results as seen in Table 6 were not consistent with part of a previous study conducted by Bakken (1997) in which higher RPE values were seen for BK pedaling at 100 spm. However, when the subjects pedaled at 120 spm there was no difference. The results were also consistent with Kravitz et al. (1998). They found that FR and BK pedaling at 125 spm produced similar RPE values.

The results of the present study were consistent with the literature, and indicated that RPE is highly correlated with HR and exercise intensity (ACSM, 2000). The intensity did not change between the two strides and the subjects perceived FR and BK pedaling at 100 spm the same.

Main Effect for Resistance

For the present study, the resistance was set at three different resistance levels for each condition. This was done intentionally to determine the effect of increased

resistance on the physiological and perceptual responses. The three resistance levels that were used for the main effect of Resistance were: (a) 4, (b) 8, and (c) 12.

Heart Rate (HR) and HR as a Percent of Maximum HR (% HR max)

As seen in Tables G₁ and G₂, the main effect of Resistance produced a significant difference for HR and % HR max. This indicated that HR increased as the resistance increased. This was supported by the literature review by Wilmore and Costill (1994), who stated that HR increases directly in proportion with exercise resistance.

Relative VO₂ and Relative VO₂ as a Percent of VO₂ max (%VO₂ max)

The main effect for Resistance produced a significant difference for relative VO₂ (Table G₃) and % VO₂ max (Table G₄). This indicated that the VO₂ responses increased as the resistance increased. These findings were supported by the literature, which states that VO₂ is directly related to intensity (Wilmore & Costill, 1994; Foss & Keteyian, 1998).

Absolute and Relative Caloric Expenditure (CE)

The main effect for Resistance produced a significant difference for absolute CE (Table G₅) and relative CE (Table G₆). This indicated that the energy cost of the exercise increased as the resistance increased. . The results were supported by the

literature, which stated that the energy cost during exercise increases with intensity (Foss & Keteyian, 1998).

RPE for the Arms, Chest, Legs and Overall Body

The main effect for Resistance produced a significant difference for RPE/A (Table G₇), RPE/C (Table G₈), RPE/L (Table G₉), and RPE/O (Table G₁₀). This is seen in Table 6 where the RPE values increased with the resistance. The results of the present study were in agreement with the literature, which stated that RPE is highly correlated with HR and exercise intensity (ACSM, 2000).

Interaction Effects

The first order interactions were: (a) Arms \times Stride, (b) Arms \times Resistance, (c) Stride \times Resistance; and the second order interaction was: (a) Arms \times Stride \times Resistance. Significant first order interactions were noted for Arms \times Stride, Arms \times Resistance, and Stride \times Resistance. There were no significant second order interactions for any of the variables. Also the results in Chapter IV showed that there were no significant interactions for the dependent variables HR and % HR max.

Interaction Effect for Arms \times Stride

The significant interaction effect of Arms \times Stride for absolute and relative CE can be seen in Figures 3 and 4. When the subjects used the moving handlebars the absolute and relative CE decreased between FR and BK pedaling. However, when the

subjects used the stationary handlebars the absolute and relative CE increased between FR and BK pedaling.

Although a significant interaction was noted ($p < .05$), the changes in absolute and relative CE were not practically significant. The results showed a decrease of $0.30 \text{ kcal} \cdot \text{min}^{-1}$ between AF and AB, and an increase of $0.05 \text{ kcal} \cdot \text{min}^{-1}$ between NF and NB for absolute CE. There was a decrease of $0.0036 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ between AF and AB, and an increase of $0.0012 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ between AF and AB for relative CE. These differences are most likely a result of measuring CE through indirect calorimetry.

Interaction Effect for Arms \times Resistance

The interaction effect of Arms \times Resistance produced significant differences in RPE/L and RPE/O as indicated by Figures 3 and 4. The RPE/L and RPE/O values for stationary and moving handlebars were similar at resistance level 4, but did not increase at the same rate as resistance increased. When subjects used the moving handlebars, RPE/L and RPE/O values recorded were less when compared to the values recorded for stationary handlebars at resistance level 12. This would indicate that subjects perceived the exercise as less strenuous for legs and overall body at higher resistance levels when moving handlebars were used.

This significant first order interaction between main effects Arms and Resistance for RPE/L and RPE/O most likely occurred because the values recorded at resistance 4 were similar and different at resistance 12. The mean RPE/L values at

resistance 4 were $8.17 \pm .19$ and $8 \pm .2$ for moving and stationary handlebars respectively. The mean RPE/L values at resistance 12 were $10.54 \pm .33$ and $11.17 \pm .37$ for moving and stationary handlebars respectively, which produced an increase of 2.37 and 3.17 for moving and stationary handlebars respectively.

The mean RPE/O values at resistance 4 were $7.96 \pm .13$ and $7.75 \pm .14$ for moving and stationary handlebars respectively. The mean RPE/O values at resistance 12 were $10 \pm .30$ and $10.79 \pm .32$ for moving and stationary handlebars, which produced an increase of 2.04 and 3.04 for moving and stationary handlebars respectively.

Interaction Effect for Strides \times Resistance

The interaction effect of Stride \times Resistance produced significant interactions for relative VO_2 , % VO_2 max, RPE/C, and RPE/L. As Figures 4 and 5 illustrate, relative VO_2 and % VO_2 max did not increase at the same rate for BK pedaling as they did for FR pedaling when resistance increased.

This significant first order interaction between main effects Stride and Resistance for relative VO_2 and % VO_2 max most likely occurred because the results recorded at resistance 4 were similar for strides. The mean VO_2 values for FR and BK pedaling at resistance 4 were $13.55 \pm .50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $12.75 \pm .39 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ respectively, and $21.35 \pm .89 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for FR pedaling and $21.82 \pm .81 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for BK pedaling at resistance 12. Although a significant interaction ($p < .05$) was noted, there was not a significant practical difference. There was an increase of

7.80 ml·kg⁻¹·min⁻¹ and 9.07 ml·kg⁻¹·min⁻¹ for FR and BK pedaling respectively between resistance levels 4 and 12, a difference of 1.27 ml·kg⁻¹·min⁻¹. A similar interaction effect was noted for % VO₂ max. The results showed that mean % VO₂ max at resistance 4 was 30.11 ± 1.38% and 28.34 ± 1.13% for FR and BK pedaling respectively. At resistance 12 the values were 47.44 ± 2.36% for FR pedaling and 48.53 ± 2.29% for BK pedaling. There was an increase of 17.33% for FR pedaling, and an increase of 20.19% for BK pedaling between resistance levels 4 and 12, a difference of 2.86%.

A similar interaction effect was noted for RPE/C and RPE/L as seen Figures 6 and 7. Similar values of RPE/C and RPE/L were recorded for FR and BK pedaling at resistance 4. When resistance was set at level 12, higher values of RPE/C and RPE/L were recorded for BK pedaling. This would indicate that BK pedaling at higher resistance level was perceived as more strenuous than FR pedaling.

This significant first order interaction between main effects Stride and Resistance for RPE/C and RPE/L most likely occurred because the results recorded at resistance 4 were similar and did not increase at the same rate as resistance increased to level 12. The mean RPE/C values recorded for FR pedaling were 6.71 ± .11 at resistance 4, and 7.13 ± .16 at resistance 12. The mean RPE/C values recorded for BK pedaling were 6.67 ± .11 at resistance 4, and 7.38 ± .27 at resistance 12. There was an increase of 0.42 for FR pedaling and an increase of 0.61 for BK pedaling between resistance levels 4 and 12, a significant statistical difference of 0.19. This difference was not a significant practical difference. Then mean RPE/L values recorded for FR

pedaling were $8.13 \pm .19$ at resistance 4, and $10.58 \pm .42$ at resistance 12. The mean RPE/L values recorded for BK pedaling were $8.04 \pm .23$ at resistance 4, and $11.13 \pm .34$ at resistance 12. There was an increase of 2.45 for FR pedaling and 3.09 for BK pedaling, a significant difference of 0.64. This difference was not a significant practical difference.

Summary of Findings

The following findings are a summary of the results discussed in this chapter.

1. The use of moving handlebars did not increase the physiological responses as compared to stationary handlebars.
2. FR and BK pedaling produced similar physiological and perceptual responses.
3. Higher resistance levels produced higher physiological and perceptual responses.
4. The use of moving handlebars produced higher RPE/A and RPE/C values as compared to stationary handlebars.
5. Although there were first order interactions, they did not produce any significant practical difference.

Conclusions

From the results of this study, it was concluded that the Precor® EFX™ 556 elliptical is a reliable modality for developing and maintaining cardiovascular fitness. However, the moving handlebars did not increase the intensity of the exercise during FR or BK pedaling. Therefore, the trainer Precor® EFX™ 556 elliptical did not provide a total body workout as stated by the manufacturers (Precor, 2001). In order to provide a total body exercise the moving handlebars should not be connected to the foot pedals, instead they should have a separate mechanism that allows the user to increase or decrease the upper body resistance independently.

Recommendations

The following recommendations are suggested for further research.

1. Compare physiological and perceptual responses at greater resistance levels, and stride rates than the ones used in the present study.
2. Investigate the effects during FR or BK pedaling without arm support while using a natural arm swing.
3. Examine EMG activity of major upper and lower body muscles during FR or BK elliptical pedaling with the use of moving handlebars, stationary handlebars, and no arm support at the same but also greater resistance levels, and stride rates.

Appendix A

Human Subject Institutional Review Board
Approval Forms

Human Subjects Institutional Review Board PROJECT APPROVAL REVIEW FORM

Western Michigan University's policy states that "the HSIRB's review of research on a continuing basis will be conducted at appropriate intervals but not less than once per year." In compliance with that policy, the HSIRB requests the following information:

PROJECT TITLE: Physiological and Biomechanical Assessment of Two Different Elliptical Trainers

HSIRB Project Number: 00-10-05

Date of Review Request: 09/17/00

Date of Last Approval: 10/20/00

PRINCIPAL INVESTIGATOR OR ADVISOR

Name: Mary L. Dawson

Department: HPER

Electronic Mail Address: mary.dawson@wmich.edu

(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR

Name: Roger Zabik

Department: HPER

Electronic Mail Address: roger.zabik@wmich.edu

(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR

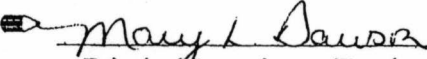
Name: Tim Michael

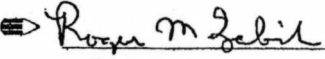
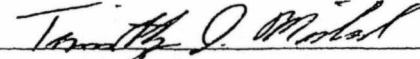
Department: HPER

Electronic Mail Address: tim.michael@wmich.edu

1. The research, as approved by the HSIRB, is completed.
☐ Yes (Continue with items 5-7 below.) ☒ No (Continue with items 2-5 below.)
2. Have there been changes in Principal or Co-Principal Investigators? ☐ Yes ☒ No
 (If yes, provide details on an attached sheet.)
3. Is the approved protocol still accurate and being followed with respect to:
 (If no to any item below, provide the details on an attached sheet.)

a. Procedures	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
b. Subjects	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
c. Design	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
d. Data collection	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
4. Has any instrumentation been modified or added to the protocol? ☐ Yes ☒ No
 (If yes, attach new instrumentation or indicate the modifications made.)
5. Have there been any adverse events which need to be reported to the HSIRB? ☐ Yes ☒ No
 (If yes, provide details on an attached sheet.)
6. Current total number of subjects enrolled: 30 Current number of subjects in the control group: 0
7. Provide copies of the consent documents signed by the last two subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most current consent document being used. (Remember to include a clean original of the consent documents to receive a renewed approval stamp.)


9-14-01
 Principal Investigator/Faculty Advisor Signature Date



9-14-01
 Co-Principal or Student Investigator Signature Date

Approved by the HSIRB:


9-18-01
 HSIRB Chair Signature Date

Human Subjects Institutional Review Board PROJECT APPROVAL REVIEW FORM

Western Michigan University's policy states that "the HSIRB's review of research on a continuing basis will be conducted at appropriate intervals but not less than once per year." In compliance with that policy, the HSIRB requests the following information:

PROJECT TITLE:

HSIRB Project Number:

Date of Review Request:

Date of Last Approval:

PRINCIPAL INVESTIGATOR OR ADVISOR

Name:

Department: Electronic Mail Address:

(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR

Name: George Hajjefremides

Department: HPER Electronic Mail Address: giorgiohajji@hotmail.com

(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR

Name: Alicia Armour

Department: HPER Electronic Mail Address: alicia.armour@wmich.edu

1. The research, as approved by the HSIRB, is completed.
☐ Yes (Continue with items 5-7 below.) ☐ No (Continue with items 2-5 below.)
2. Have there been changes in Principal or Co-Principal Investigators?
 (If yes, provide details on an attached sheet.) ☐ Yes ☐ No
3. Is the approved protocol still accurate and being followed with respect to:
 (If no to any item below, provide the details on an attached sheet.)
 - a. Procedures ☐ Yes ☐ No
 - b. Subjects ☐ Yes ☐ No
 - c. Design ☐ Yes ☐ No
 - d. Data collection ☐ Yes ☐ No
4. Has any instrumentation been modified or added to the protocol?
 (If yes, attach new instrumentation or indicate the modifications made.) ☐ Yes ☐ No
5. Have there been any adverse events which need to be reported to the HSIRB?
 (If yes, provide details on an attached sheet.) ☐ Yes ☐ No
6. Current total number of subjects enrolled: Current number of subjects in the control group:
7. Provide copies of the consent documents signed by the last two subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most current consent document being used. (Remember to include a clean original of the consent documents to receive a renewed approval stamp.)



Principal Investigator/Faculty Advisor Signature

Date



Alicia Armour

9-13-01

Co-Principal or Student Investigator Signature

Date

George Hajjefremides

9-13-01

Approved by the HSIRB:



May Zagorac

9-18-01

HSIRB Chair Signature

Date

Appendix B
Recruitment Script

Memo

To: All HPER faculty and staff
From: Giorgio Haji, Alicia Armour
Re: Thesis and data collection
Date: September 17, 2001

Hello everyone! The semester is on its way and we have favors to ask of all of you. If you would be so kind as to read the attached Subject Recruitment form in all of your classes for us and have the students write their names and numbers on the provided form. All forms may be placed in Haji's mailbox (4th floor SRC). We are willing to speak in your classes if you prefer us to do so. We are hoping to begin collecting data by the end of the month and continue through October. Haji needs about 30 subjects and Alicia needs at least 50. If you have questions about either thesis you can ask Haji, Alicia, Dr. Michael, Dr. Zabik, or Dr. Dawson. Thank you for your time and cooperation.

Subject Recruitment Script

Drs. Dawson, Michael, and Zabik are in need of volunteers to participate in a research project that they are conducting titled *Physiological and Biomechanical Assessment of Two Different Elliptical Trainers*. The study will involve subjects between 18-35 years of age who are “low risk” according to ACSM’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 one of the following:

1. Using the elliptical trainer with the moveable handlebars and with the stationary handlebars at a low, medium, and medium high resistance settings (settings 5, 10, and 15 on the Precor Elliptical Trainers). Participation in this phase of the study will involve four, 45-minute sessions.
2. Using the elliptical trainer at a low, medium, and medium high resistance settings (settings 5, 10, and 15 on the Precor Elliptical Trainers) and at three grades; level, low, and medium (settings 5, 10, and 15 on the Precor Elliptical Trainers). Both a backward and a forward cycling motion will be studied. Participation in this phase of the study will involve three, 45-minute sessions.
3. Exercising on the elliptical trainer as the workloads, every 3 minutes, become more difficult. The exercise session will stop when heart rate gets to about 160 bpm (the average heart rate for most normal aerobic workouts). Your VO_2 max will also be measured. Participation in this phase of the study involves five sessions; two, 45-minute sessions to test VO_2 max and three, 30-minute sessions of a graded exercise test using the elliptical trainer.

You have the option to voluntarily terminate your involvement in the study for any reason. Your participation during the study will not have any effect on your status as a student at Western Michigan University. All test information will be kept confidential. If you are between the ages of 18-35 years of age, exercise 2-3 times per week, and are interested in getting more information or volunteering for the study, please print your name and phone number below or contact Dr. Dawson at 616 387-2546, Dr. Michael at 616 387-2691, or Dr. Zabik at 616 387-2542.

Thank you!

Name	Phone	Name	Phone
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Appendix C
Health Screening Form

Physical Activity Readiness Questionnaire

Name: _____
 WMU Phone: _____

Date: _____
 Age: _____

This form has been designed to help identify whether or not you should consult your personal physician before beginning an exercise program.

Please read the following questions carefully and check (✓) the appropriate answer. Answer the questions to the best of your ability.

Yes	No	
_____	_____	1. Have you ever had a stroke, heart attack, or heart surgery?
_____	_____	2. Do you frequently suffer from chest pain?
_____	_____	3. Have you ever been told that you have a bone, joint, or muscle problem that could be made worse by physical activity?
_____	_____	4. Do you have any major illnesses that could be made worse by physical activity?
_____	_____	5. Have you ever been told that you have a heart or blood vessel problem?
_____	_____	6. Are you over the age of 45 and just beginning an exercise program?
_____	_____	7. Do you have blood pressure greater than 140/90 or cholesterol higher than 240 mg/dl?

If you answered **yes to any** of the above questions, it is recommended that you receive medical clearance from your physician before participating in any physical activity.

Exercise Participation Agreement

I have voluntarily chosen to participate in the research conducted in the Exercise Physiology lab at the Student Recreation Center, Western Michigan University. I answered the medical questions above to the best of my ability and affirm that my physical condition is good and I have no conditions that prevent me from participating in fitness activities. I understand that the researchers in this study recommend improving physical fitness through an exercise plan consisting of gradual warm-up, aerobic exercise, strength development, and a cool-down. I also realize that participation is at my own pace and that I am free to discontinue my participation at any time. Further more, I agree to self-limit my exertion through good judgment and to terminate any activity immediately if it exceeds my personal limitations.

I understand that by signing this agreement, I hereby waive and release Western Michigan University, its president, Board of Trustees, staff and employees and any and all persons or organizations involved in any way from any and all claims, liabilities or demands of any kind as a result of an injury, loss or adverse health condition arising from my participation in this activity. I realize that I am not required to participate in this activity, but do so voluntarily.

I affirm that I have read and fully understand the above document and I wish to participate in fitness activities.

 Signature of Participant

 Date

Appendix D
Consent Form

WESTERN MICHIGAN UNIVERSITY

H. S. I. R. B.

Approved for use for one year from this date:

SEP 18 2001

x *Mary Zagury*
HSIRB Chair

Western Michigan University
Department of Health, Physical Education, and Recreation
Principal Investigators: Drs. Mary Dawson, Tim Michael, and Roger Zabik
Student Investigators: Alicia Armour and George Hajieffremides

I have been invited to participate in a research project that will study the physiological and biomechanical effect of exercise when using an elliptical trainer. The research will describe the alignment of the lower extremities during a complete cycle of motion, the cardiopulmonary (heart and lungs) efficiency at various grades and elevations, and my perceived exertion. I will exercise on one Precor, elliptical trainer, the EFX 546 or the EFX 556. The research project in which I am involved is part of a project conducted by Drs. Dawson, Michael, Zabik, and students (Katherine Wehmeyer and Erica McManus) 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. The extent of my participation involves the paragraph(s) checked below. I will not be involved in those paragraphs that are not checked.

- ☒ My consent to participate in this project indicates that I will be asked to attend four, 45-minute sessions. I will meet the researchers in the Student Recreation Building, 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 four sessions I will complete one of the following exercise conditions on the elliptical trainer EFX 556: (1) Arms on moveable handles, legs move forward; (2) Arms on moveable handles, legs move backward; (3) Arms on stationary handles, legs move forward; and (4) Arms on stationary handles, legs move backward. 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.
- ☐ My consent to participate in this project indicates that I will be asked to attend three, 45-minute sessions. I will meet the researchers in the Student Recreation Building, Rooms 1050-60, Western Michigan University. The 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 exercise conditions on the elliptical trainer EFX 546: (1) 5% elevation, (2) 10% elevation, and (3) 15% elevation. 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.

WESTERN MICHIGAN UNIVERSITY

H. S. I. R. B.

Approved for use for one year from this date:

SEP 18 2001

x May Zagury
HSIRB Chair

- ☒ 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 Building, 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 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 decide I can not continue or until the investigators decide that I should stop.
- ☒ During my participation on the elliptical trainer, I will breathe through a mouth piece like a swimming snorkel. To assure that I am breathing only through my mouth, I will wear nose clips. My heart rate will be monitored by wearing an adjustable elastic band with built in electrodes around my rib cage just below the breast bone. The elastic band will be under my exercise shirt. My heart rate will be recorded on a display that I will wear on my wrist like a watch.
- ☐ During my participation on the elliptical trainer my performance will be video taped so that the researchers can measure the joint angles in my lower legs during selected parts of the cyclic motion.
- ☐ At the end of my first session as a subject, I will be asked to run on a treadmill at the same rate (stepping rate) that I performed on the elliptical trainer. During the time I am running, I will be video taped.
- ☐ Prior to my participation EMG electrodes will be placed over the following muscles in my lower extremities: Front of thighs, back of thighs, back of calf, and front of calf. The site of the electrode placement will be scrubbed vigorously with a sterile alcohol pad and may be shaved to provide a better electrode contact surface. The placement of the electrodes will be on the midpoint of the longitudinal axis of the muscle.

The current testing may be of no benefit to me. Knowledge of how the body reacts to Precor elliptical trainers may help fitness specialists in who should and should not use the trainers and aid the company in design changes in future models of Precor trainers.

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 utilizes the elliptical trainer. Since the elliptical trainer does not involve impact forces the likely risk is fatigue and sore muscles and possibly falling. 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

WESTERN MICHIGAN UNIVERSITY

H. S. I. R. B.

Approved for use for one year from this date:

SEP 18 2001

x Mary Lagerwey
HSIRB Chair

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 all be coded. Dr. Dawson will keep a separate master list with the names of all participants and their code numbers. Once the data are collected and analyzed, the master list will be destroyed. The consent and data forms, a disk copy of the electronic generated data, and the video tapes will be retained for a minimum of 3 years in a locked file in the principal investigator's laboratory. A second disk copy of the electronic data will be stored by Dr. Michael for a minimum of 3 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, Dr. Timothy Michael at (616) 387-2691, or Dr. Roger Zabik at (616) 387-2542. 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 of 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 E
Bruce Protocol

The Bruce Treadmill Graded Exercise Protocol

		Time (min)					
% Grade	3	6	9	12	15	18	
10	1.7 mph						
12		2.5 mph					
14			3.4 mph				
16				4.2 mph			
18					5.0 mph		
20						5.5 mph	

Appendix F
Borg's RPE Scale

Borg's Category Scale

RPE Scale	Perceptual Responses
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Appendix G

ANOVA Summary Tables

Table G₁
ANOVA Summary for HR

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	8.03	1.00	8.03	.13	.72
Error (A)	657.14	11.00	59.74		
Stride (S)	420.25	1.00	420.25	2.67	.13
Error (S)	1736.25	11.00	157.84		
Res (R)	20661.56	1.08	19086.39	62.07	.00
Error (R)	3661.94	11.91	307.53		
A × S	103.36	1.00	130.36	.64	.44
Error (A × S)	1784.14	11.00	162.19		
A × R	4.06	2.00	2.03	.20	.82
Error (A × R)	223.78	22.00	10.17		
S × R	24.00	1.29	18.55	.73	.44
Error (S × R)	360.50	14.23	25.33		
A × S × R	19.06	2.00	9.53	.92	.41
Error (A × S × R)	228.44	22.00	10.38		

Table G₂
ANOVA Summary for % HR max

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	2.32	1.00	2.32	.15	.71
Error (A)	174.34	11.00	15.85		
Stride (S)	113.95	1.00	113.95	2.75	.13
Error (S)	456.03	11.00	41.46		
Res (R)	5598.91	1.08	5175.18	64.15	.00
Error (R)	960.03	11.09	80.67		
A × S	22.21	1.00	22.21	.53	.48
Error (A × S)	458.48	11.00	41.68		
A × R	1.09	2.00	.55	.21	.82
Error (A × R)	58.40	22.00	2.66		
S × R	7.87	1.31	6.03	.91	.39
Error (S × R)	95.60	14.37	6.65		
A × S × R	5.19	2.00	2.60	.97	.39
Error (A × S × R)	58.62	22	2.66		

Table G₃
ANOVA Summary for Relative VO₂

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	.08	1.00	.08	.02	.90
Error (A)	47.49	11.00	4.32		
Stride (S)	3.21	1.00	3.21	.52	.49
Error (S)	67.69	11.00	6.15		
Res (R)	1830.49	1.08	1700.80	86.30	.00
Error (R)	233.32	11.84	19.71		
A × S	5.18	1.00	5.18	4.60	.06
Error (A × S)	12.39	11.00	1.13		
A × R	.36	2.00	.18	.22	.80
Error (A × R)	17.68	22.00	.80		
S × R	10.86	2.00	5.43	5.08	.02
Error (S × R)	23.50	22.00	1.07		
A × S × R	.93	1.29	.72	.41	.58
Error (A × S × R)	25.00	14.14	1.78		

Table G₄
ANOVA Summary for % VO₂max

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	1.31	1.00	1.31	.06	.82
Error (A)	258.51	11.00	23.50		
Stride (S)	14.80	1.00	14.80	.49	.50
Error (S)	333.22	11.00	30.29		
Res (R)	9060.09	1.08	8412.32	78.00	.00
Error (R)	1277.64	11.85	107.85		
A × S	25.15	1.00	25.15	4.70	.05
Error (A × S)	58.81	11.00	5.35		
A × R	1.43	2.00	.72	.18	.84
Error (A × R)	87.13	22.00	3.96		
S × R	55.58	2.00	17.79	5.27	.01
Error (S × R)	116.10	22.00	5.28		
A × S × R	5.32	1.29	4.13	4.81	.55
Error (A × S × R)	121.77	14.19	8.58		

Table G₅
ANOVA Summary for Absolute CE

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	.32	1.00	.32	.53	.48
Error (A)	6.66	11.00	.61		
Stride (S)	.56	1.00	.56	.72	.41
Error (S)	8.55	11.00	.78		
Res (R)	227.82	2.00	113.91	345.71	.00
Error (R)	7.25	22.00	.33		
A × S	1.14	1.00	1.14	8.46	.01
Error (A × S)	1.48	11.00	.13		
A × R	.13	2.00	.06	.97	.40
Error (A × R)	1.45	22.00	.07		
S × R	.58	1.27	.45	2.10	.17
Error (S × R)	3.01	13.96	.22		
A × S × R	.08	2.00	.04	.23	.80
Error (A × S × R)	3.89	22.00	.18		

Table G₆
ANOVA Summary for Relative CE

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	.03	1.00	.03	.26	.62
Error (A)	.01	11.00	.01		
Stride (S)	.06	1.00	.06	.44	.52
Error (S)	.01	11.00	.01		
Res (R)	.05	1.12	.04	94.08	.00
Error (R)	.05	12.35	.04		
A × S	.02	1.00	.02	9.71	.01
Error (A × S)	.02	11.00	.02		
A × R	.03	2.00	.02	1.21	.32
Error (A × R)	.03	22.00	.01		
S × R	.01	1.29	.08	2.44	.14
Error (S × R)	.05	14.15	.03		
A × S × R	.09	2.00	.04	.16	.85
Error (A × S × R)	.06	22.00	.03		

Table G₇
ANOVA Summary for RPE for Arms

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	29.34	1.00	29.34	82.55	.00
Error (A)	3.91	11.00	.36		
Stride (S)	.07	1.00	.07	.01	.92
Error (S)	6.58	11.00	.60		
Res (R)	4.29	2.00	2.15	13.33	.00
Error (R)	3.54	22.00	.16		
A × S	.56	1.00	.56	1.54	.24
Error (A × S)	4.02	11.00	.37		
A × R	1.26	2.00	.63	3.28	.06
Error (A × R)	4.24	22.00	.19		
S × R	.10	1.28	.08	.52	.60
Error (S × R)	2.07	14.08	.15		
A × S × R	.13	2.00	.06	1.32	.29
Error (A × S × R)	1.04	22.00	.05		

Table G₈

ANOVA Summary for RPE for Chest

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	17.36	1.00	17.36	22.54	.00
Error (A)	8.47	11.00	.77		
Stride (S)	.03	1.00	.03	.02	.88
Error (S)	12.47	11.00	1.13		
Res (R)	8.85	1.18	7.51	10.08	.01
Error (R)	9.65	12.97	.74		
A × S	.03	1.00	.03	.02	.90
Error (A × S)	18.47	11.00	1.68		
A × R	.51	2.00	.26	1.22	.32
Error (A × R)	4.65	22.00	.21		
S × R	.93	2.00	.47	3.98	.03
Error (S × R)	2.57	22.00	.12		
A × S × R	.93	1.14	.81	.97	.36
Error (A × S × R)	10.57	12.58	.84		

Table G₉
ANOVA Summary for RPE for Legs

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	2.78	1.00	2.78	2.03	.18
Error (A)	15.06	11.00	1.37		
Stride (S)	.25	1.00	.25	.11	.75
Error (S)	25.92	11.00	2.36		
Res (R)	191.93	2.00	95.97	104.33	.00
Error (R)	20.24	22.00	.92		
A × S	.25	1.00	.25	.05	.82
Error (A × S)	50.92	11.00	4.63		
A × R	3.93	2.00	1.97	10.21	.00
Error (A × R)	4.24	22.00	.19		
S × R	3.88	1.32	2.93	4.28	.05
Error (S × R)	9.96	14.57	.68		
A × S × R	.88	1.19	.74	.64	.46
Error (A × S × R)	14.96	13.09	1.14		

Table G₁₀

ANOVA Summary for RPE for Overall Body

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Arms (A)	2.51	1.00	2.51	3.41	.09
Error (A)	8.08	11.00	.73		
Stride (S)	.06	1.00	.06	.04	.85
Error (S)	18.85	11.00	1.71		
Res (R)	160.06	1.13	80.03	102.89	.00
Error (R)	17.11	14.49	1.18		
A × S	.07	1.00	.07	.00	.97
Error (A × S)	40.24	11.00	3.66		
A × R	6.06	2.00	3.03	10.90	.00
Error (A × R)	6.11	22.00	.28		
S × R	2.17	2.00	1.08	2.23	.13
Error (S × R)	10.67	22.00	.49		
A × S × R	2.39	1.23	1.94	1.45	.26
Error (A × S × R)	18.11	13.55	1.34		

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