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# Cardiovascular, Metabolic, Electromyographic, and RPE Responses to Isotonic versus Isokinetic Exercise Performed on the Monark and Fitron Bicycle Ergometers

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CARDIOVASCULAR, METABOLIC, ELECTROMYOGRAPHIC, AND RPE RESPONSES TO ISOTONIC VERSUS ISOKINETIC EXERCISE PERFORMED ON THE MONARK AND FITRON BICYCLE ERGOMETERS

(TITLE)

BY

Patrice Annette Keil

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# ABSTRACT

## Cardiovascular, Metabolic, Electromyographic, and RPE Responses to Isotonic versus Isokinetic Exercise Performed on the Monark and Fitron Bicycle Ergometers

Patrice Annette Keil

The purpose of this study was to determine if any differences exist in relative efficiency of the subjects when riding a Monark bicycle ergometer as compared to a Fitron bicycle ergometer ridden at the same work rate. This efficiency was determined from levels of oxygen consumption, exercise heart rates, ratings of perceived exertion, blood pressure, and electromyographic recordings of four right leg muscles during exercise bouts on the two different bicycle ergometers.

Seventeen apparently healthy male subjects aged 42 to 78 years performed two tests, one on the Monark bicycle ergometer and one on the Fitron bicycle ergometer. Each test was a submaximal test in which the subject rode the bike until a steady-state in heart rate and oxygen consumption was reached. The work rate for each individual was chosen to match his normal training heart rate.

A t-test for dependent observations was used to determine the significance of difference of the mean oxygen consumption, heart rate, blood pressure, rating of perceived exertion, average pedal count, and electromyographic activity. There was a statistically significant difference ($p<0.05$) in the mean values for oxygen consumption,

heart rate, blood pressure, and rating of perceived exertion during exercise rides on the Monark and Fitron bicycle ergometers. These values were all found to be significantly higher for exercise performed on the Monark bicycle ergometer. No statistically significant difference was found for average pedal count or total duration of electrical activity of the vastus lateralis, biceps femoris, tibialis anterior, and gastrocnemius leg muscles between tests performed on the Monark and Fitron bicycle ergometers as measured by the electromyographic recordings.

## DEDICATION

This paper is dedicated to my parents, Donald and Patricia Keil for their patience, encouragement, and sacrifice throughout my life. No words could possibly express the thanks and the appreciation I owe them. Mom and Dad, you've always been there for me and I would never have made it through the last two years, or this paper, without your unconditional love and support. I just wanted to say thank you and I Love You.

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A very special and loving thanks from the author goes to Mr. Jack Jeffries for all the endless hours spent in front of the computer to help complete many important sections of this study. The author also wishes to thank her brother, Brian Keil and sister, Lori Jeffries for always being there for me as we grew up together and for providing love and support when the author needed it the most.

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# CHAPTER 1

## Introduction

Exercise physiologists consider the bicycle ergometer to be a very important and valuable tool to assess functional capacity in fit as well as unfit subjects. Bicycle ergometers are also used extensively in exercise prescription for both cardiac rehabilitation patients and healthy individuals. There are many advantages to using this mode of exercise as compared to others. A major advantage is that work performed is specific and can be predetermined.

In this study, two types of bicycle ergometers were compared to investigate which bicycle ergometer provides the most efficient workout in terms of the work accomplished divided by the energy expended to do that work. A difference between these two bicycle ergometers was expected because of the types of exercise they provide.

The Fitron, produced by Cybex, is a relatively new type of bicycle ergometer which operates on the principle of isokinetic exercise. An accommodating resistance is provided while the individual pedals at a constant rate. This means that the force exerted by the individual during cycling is perfectly matched by the Fitron throughout this entire range of motion (Cybex, 1987). Cybex (1987) claims this provides a smoother and more efficient workout while producing less local muscular fatigue when pedalling at higher work rates.

Cybex (1987) also claims that the smooth, efficient resistance provided by isokinetics makes this type of exercise on this bicycle ergometer less stressful on the bones and joints. The Fitron uses a hydraulic tension-producing system. There is no momentum generated nor is there any benefit from use of a large and heavy flywheel on the Fitron. Alternatively, this hydraulic system permits the user to pedal through the weakest and strongest ranges of motion at the most desirable (or even maximal) work rates, without losing any energy attempting to accelerate a large and heavy flywheel.

The Fitron allows the exercise rate to be preselected based on training or therapy needs. Once a pedalling rate has been selected, attempting to pedal with increased force will not result in acceleration as in the isotonic, or Monark bicycle ergometer. Attempting to pedal faster on the Fitron at a preselected pedal rate produces more work at that selected rate, not an increase of that rate.

The Monark bicycle ergometer is an example of an isotonic device also used for training and therapy. This ergometer provides exercise and resistance using a large and heavy flywheel. Use of this heavy flywheel provides momentum which allows the user to maintain a smooth pedalling motion. This momentum also provides a means for the user to pedal through the weakest part of the bicycling range of motion, which is described as being when the pedal cranks are perpendicular to the floor (Cybex, 1987).

It is important to determine which bicycle ergometer would be the preferred apparatus utilized in exercise prescription for apparently healthy individuals as well as patients in a cardiac rehabilitation program. New information on this subject could change the attitudes and feelings of exercise physiologists, cardiologists, and exercise specialists concerning how exercise can be prescribed using the isokinetic device for apparently healthy individuals as well as for patients participating in a cardiac rehabilitation program.

## Purpose of the Study

The purpose of this study was to determine if any differences exist in the relative efficiency of subjects when riding a Fitron bicycle ergometer when compared to a Monark bicycle ergometer ridden at the same work rate. This efficiency was determined from levels of oxygen consumption, exercise heart rates, ratings of perceived exertion, blood pressures, and electromyographic recordings of four right leg muscles during exercise bouts on the two different bicycle ergometers.

## Null Hypotheses

1. There is no difference in the relative efficiency of subjects when riding a Fitron bicycle ergometer compared to a Monark bicycle ergometer as determined by differences in oxygen consumption at comparable work rates.

2. There is no difference in the heart rates of subjects when riding a Fitron bicycle ergometer compared to a Monark bicycle ergometer at comparable work rates.

3. There is no difference in the blood pressures of subjects when riding a Fitron bicycle ergometer compared to a Monark bicycle ergometer at comparable work rates.

4. There is no difference in the ratings of perceived exertion (Borg scale) of subjects when riding a Fitron bicycle ergometer as compared to a Monark bicycle ergometer at comparable work rates.

5. There is no difference in the sequence and duration of electrical activity of muscles used during one pedal cycle on the Fitron when compared to the Monark bicycle ergometer as determined by electromyographic recordings.

## Limitations

It was impossible to control the physical activity of the subjects prior to testing, other than asking them not to exercise strenuously 24 hours prior to their scheduled testing session. This study was also limited by use of healthy subjects rather than cardiac patients for the actual testing due to monitoring and safety reasons. Inability to establish the work rate calibration on the Fitron bicycle ergometer was a major limitation to this study.

## Definition of Terms

Ergometer - an apparatus or device, such as a treadmill or stationary bicycle, in which work rate can be measured; a device used for measuring the physiological effects of exercise.

Isokinetic Exercise - an accommodating type of resistive exercise; speed is held constant while tension applied against the working muscle is either increased or decreased throughout the range of motion in order to maintain that constant speed.

Isotonic Exercise - a type of exercise in which a constant external load is applied against the working muscle throughout the range of motion.

Oxygen Consumption - the rate at which oxygen is consumed per minute, that is, the power or capacity of the aerobic energy systems.

Power - work done per unit of time.

Rating of Perceived Exertion (RPE) - an overall feeling of the body's stresses during exercise as indicated by Borg's Scale.

Relative Efficiency - an indirect method of determining efficiency. A high relative efficiency can be correlated with a low oxygen consumption.

Revolutions Per Minute (RPM) - the number of pedal revolutions per minute performed by the subject.

## Assumptions

It was assumed that the anxiety produced in the Eastern Illinois University Human Performance Laboratory was similar to that experienced in any other testing environment. It was also assumed the subjects had the ability to perform the exercise according to the directions given by the investigator, and that all subjects received the same instruction and motivation during their actual tests.

# CHAPTER 2

## Review of Related Literature

The review of related literature for this study has revealed inadequate investigation of isotonic and isokinetic exercise comparisons which utilize a bicycle ergometer. Bicycle ergometers have been used as precision testing instruments for many decades. Over the last 10-15 years a new type of bicycle ergometer has been designed which uses the concept of isokinetic exercise. This type of resistive exercise is made possible by use of a device which keeps limb motion at a constant, predetermined velocity. Any effort applied meets an equal resistance in order to maintain the predetermined velocity of the limb. In addition, any increase in muscular output results in increased resistance rather than an increase in velocity. In this chapter, literature related to work efficiency, force production, electromyography, and rating of perceived exertion during work on isotonic and isokinetic bicycle ergometers will be reviewed.

### Isokinetic Exercise

Moffroid, Whipple, Hofkosh, Lowman, and Thistle (1969) performed a study of isokinetic exercise. This study resulted in establishment of norms for isokinetic exercise. These norms apply to the quadriceps and hamstring muscle groups and their force production through the range of motion at different speeds of contraction. The authors conducted their study using 60 subjects (12 men and 48 women), who were randomly selected. This study was designed to compare increases in muscular torque after four weeks of isometric, isotonic, or isokinetic exercise. Twenty subjects were placed in each isometric, isotonic, and isokinetic exercise group. The results from this study indicate that isokinetic exercise is an effective means of increasing muscular torque throughout the range of motion. Isokinetic exercise increased the amount of work a muscle was able to perform at a more rapid rate than did isometric or isotonic exercise which uses pulleys. Also, the authors determined that muscular response tends to be specific during different loading systems. That is, a muscle which is overloaded throughout a particular range of motion will increase significantly more in this range than in other, less exercised joint positions. This is a problem encountered during isometric or isotonic exercise.

Isokinetic types of devices and their common uses were discussed by Rothstein, Lamb, and Mayhew (1987). These authors described isokinetic movements as ones requiring a specific device that would provide a resistance against limb movement so that the limb could not accelerate to a point beyond the machine's preselected speed. A consequence of this is that the machine provides no resistance until that limb attempts to surpass the speed which has been previously set. For this reason, when the limb reaches the preset speed and then strives to increase beyond that speed, the limb can only proceed at a constant speed. As described earlier, the Fitron bicycle ergometer demonstrates this type of isokinetic characteristic.

Rothstein et al. (1987) also make a very important point in their study concerning calibration of the isokinetic device when measurements are being obtained for research. The authors state that calibration should be a prerequisite to testing and go even further to say how important it is that this procedure be carried out each day that tests are to be conducted. It was the authors' experience that some of these isokinetic machines can easily lose their calibration between testing sessions.

The authors concluded their study by stating that isokinetic measurements are very useful but have been frustratingly deferred by the insufficiency of satisfactory research in this area.

## Factors That Affect Energy Cost on a Bicycle Ergometer

The term efficiency is used in an exercise physiology context and is defined as the amount of work produced per liter of oxygen consumed. The work that is accomplished is the external work which refers to the application of force through a distance. During exercise, external work is measured and used for the calculation of efficiency. Energy is also expended to perform other forms of unmeasured work (internal work), which is necessary to produce the external work desired. This unmeasured work includes energy required for movement of the limbs, for respiration, for transportation of ions against their concentration gradients, and so forth. This is an important point to remember when determining efficiency of exercise.

Gaesser and Brooks (1975) tested 12 male subjects on a bicycle ergometer at pedalling rates of 40, 60, 80, and 100 RPM. Work rates of 0, 200, 400, 600, and 800 kpm/min were performed at each pedalling rate. Calculation of $VO_2$ and $VCO_2$ were done and the respiratory exchange ratio (R) was used to determine estimated caloric expenditure. This data was then used to calculate muscular efficiency. The authors found that at work rates between 200 and 800 kpm/min, there was a linear relationship of work with caloric expenditure. It was also found that increasing pedalling rate during each work rate increased caloric expenditure and simultaneously decreased muscular efficiency.

In a similar study, Pandolf and Noble (1973) obtained oxygen consumption and rating of perceived exertion (RPE) from 15 male subjects during exercise on a Monark bicycle ergometer utilizing various pedalling rates and work rates for equivalent power outputs. The authors concluded that there was no significant difference for metabolic expenditure as indicated by oxygen consumption for pedalling rates between 50 and 80 RPM at equivalent power outputs. However, there tended to be a negative relationship of RPE response at equivalent power outputs to pedalling rate, although it was found that at pedalling rates of 60 and 80 RPM there was no statistically significant difference. Oxygen consumption at pedalling rates between 100 and 120 RPM was found to be higher when compared to lower rates at the same work rate. Oxygen consumption was consistently found to be lowest for each work rate when pedalling at a rate of 60 RPM. According to these results, the indication would be that efficiency is higher when pedalling is at a rate of 60 RPM.

Knuttgen, Bonde-Peterson, and Klausen (1971) studied two subjects for aerobic energy expenditure and respiratory responses as a measure of work produced while riding on a bicycle ergometer. The authors studied and compared the two types of muscle contractions during exercise, concentric (muscle is shortening as it contracts) and eccentric (muscle is lengthening as it contracts). It was shown that heart rate and ventilation responses during exercise related closely to oxygen consumption and showed a definite increase during eccentric contraction. In addition, for the purposes of the present study, it was important to note the authors also found that during both concentric and eccentric contractions oxygen consumption was consistently lower for each power output at the pedalling rate of 60 RPM. The authors concluded their study by stating that there exists a possibility that calculated efficiency might be higher at a pedal rate of 100 RPM as compared to 60 RPM at work rates higher than those used in their study.

Whipp and Wasserman (1969) conducted a study which attempted to discuss and explain the term efficiency. The authors proposed two theories which are considered to be the basis for exercise efficiency. The first is a thermodynamic theory which describes the processes by which the chemical energy of food is converted into mechanical energy to be used by the body to function properly. The second theory presented by the authors is simply explained as the specific production of cell energy for muscular contraction. This second theory is important to the study presently being conducted because it defines efficiency as the ratio of work produced and energy expended to perform that work in the form of the breakdown of ATP (adenosine triphosphate-cell energy). Eight male subjects were tested on a bicycle ergometer. After the subjects completed an incremental exercise test which determined their anaerobic threshold, a work rate of 340 kpm/min was chosen for the test. A pedal rate of 60 RPM was also chosen to be performed during the test. The authors concluded that there is a variance in efficiency in skeletal muscle of different types. Fast-twitch muscle fibers consistently produced a lower percentage of efficiency when compared to slow-twitch muscle fibers, and these efficiencies tended to fluctuate anywhere between the range of 35-50%.

Dickinson (1929) studied the effect of pedal rate and work rate upon the efficiency of one subject while riding a bicycle ergometer. The author found that for both high and low pedalling rates the efficiency was low. In a similar study done by Garry and Wishart (1931) efficiency was determined by directly measuring the external work produced and the oxygen consumed by the subjects. The authors participated as their own subjects and rode a bicycle ergometer at nine different pedal rates (25, 28, 35, 45, 52, 70, 86, 95, and 98 RPM) and at a power output for each of these pedal rates that was described as one which could be maintained for an hour without showing muscle fatigue. The authors found that efficiency of riding on the bicycle ergometer progressively increased as pedal rate increased, with the highest efficiency being measured at a pedal rate of 52 RPM.

Pugh (1974) conducted a study on six competition cyclists. The author looked at the effect of pedal rate and work rate on the relative efficiency of the subjects as determined by oxygen consumption. In the work rate range of 900-1800 kpm/min, for pedal rates of 51-54 RPM, 74-77 RPM, and 86-88 RPM efficiency was found to remain constant. The author also found that for work rates below 900 kpm/min, while pedalling at rates of 74-77 RPM and 86-88 RPM, the efficiency decreased with each progressively lower work rate. The author noted that at all work rates, the pedal rates between 86-88 RPM consistently produced the lowest efficiency.

Three male subjects were tested by Seabury, Adams, and Ramey (1977). These three subjects rode a Monark bicycle ergometer at eight different pedalling rates between 30-120 RPM and four different power outputs of 0, 81.7, 163.4, and 196.1 watts. Oxygen consumption during the rides was used to determine energy expenditure. The authors found that energy expenditure increased progressively as pedal rate and power output increased.

Croisant and Boileau (1984) had nine healthy young men perform tests on a bicycle ergometer at five different pedal rates (20-100 RPM) with five different brake loads at each pedal rate (0-4 kp). The authors found that oxygen consumption increased curvilinearly with increases in pedal rate. Oxygen consumption was also found to increase curvilinearly with increases in brake load when the pedal rate was held constant. The authors concluded their study by stating that the energy cost of riding a bicycle ergometer is the result of both the rate and force with which the work is produced. The authors also stated that this energy cost is not linearly related to the amount of work the subject produces while riding the bicycle ergometer.

Ericson (1988a) performed a study which determined power output at three different joints of the lower body during exercise on a bicycle ergometer at different pedal rates and work rates. The subjects were tested at three different work rates at a constant pedalling rate of 60 RPM. They also pedalled at four different pedal rates of 40, 60, 80, and 100 RPM while a constant force of 2 kp was applied. The author found that as work on the bicycle ergometer increased there was an instantaneous increase in muscular power output in all major muscle groups.

In the studies reviewed, the authors seemed to concur that work on a bicycle ergometer is achieved at a lower energy cost when performed with a pedalling rate and work rate that is of a moderate level. In the majority of the studies, the best pedalling rate was found to be between 40 and 60 RPM. Work performed above or below this rate of pedalling was found to be less efficient than work performed at a similar level using a higher or lower pedalling rate.

Force Production Throughout the Range of Motion

Application of force on the pedal and crank during work on a bicycle ergometer is maximal when the position of the pedal is in the front at approximately 90 degrees to the verticle line of the chainring. Several studies have been done which measure the pedal forces applied and work performed on a stationary bicycle ergometer. Hoes, Binkhorst, Smeekes-Kuyl, and Vissers (1968) suggested that at any given time during one pedal revolution, the mean force is expected to be the result of forces of different levels of magnitude and direction. The effects the authors have described of the inability to exert force on the pedals in the direction in which they are moving are occurrences often observed at increased work rates and lower pedalling rates performed on bicycle ergometers. Results from this study basically provided some insight as to the way a subject, exercising at different work rates, exerts a force on the pedal and crank of a bicycle ergometer.

Sargeant and Davies (1977) performed a study of one- and two-leg cycling that measured the pattern of force exerted on both cranks by means of a specially adapted stationary bicycle ergometer. The mean peak force observed in each pedalling cycle was found to be linearly related to the amount of work load applied. In addition, no significant differences were observed between right and left legs in the mean peak force and work load relationship in one-leg exercise. But in two-leg exercise, a slightly but significantly greater force was determined to be exerted by the right leg.

Sargeant, Charters, Davies, and Reeves (1978) measured forces exerted on the right and left cranks of a bicycle ergometer. These forces were measured simultaneously and separately by a procedure used in the study by Hoes et al. (1968). However, this procedure was adapted so that measurements could be made continuously over extended periods of exercise. The resulting measurements of force were obtained by two methods. In the first method, a progressive exercise test was used. Over a two-minute period at each work load, the peak force generated on a crank was measured during each revolution. From this information, a mean value for peak force produced was calculated. In the second method, the force was measured during a normal revolution at each 15 degree interval from a zero baseline. Work performed on the crank was determined according to the area between the force record and the zero baseline. This area could be determined, assuming a mean force and constant speed were used. The distance traveled in each 15 degree interval was calculated from the 17.8 cm crank length known. The revolution that was observed to be the closest in peak force to the mean force measured over the two minutes recorded in the first method, was the revolution to be used for the final force measurement.

Results of this study revealed a consistently higher oxygen consumption for a given work output in one- compared with two-leg exercise, which indicates a reduction in relative efficiency in one-leg exercise as compared to two-leg exercise. In addition, there was no significant difference found between the right and left legs in mean peak force applied for a given work output in one-leg exercise. The relationship of mean peak force and work output was found to be linear in both one- and two-leg exercise.

Ericson and Nisell (1988) exercised six male subjects aged 20 to 31 years on a bicycle ergometer. The variables that were measured during the tests were power output, pedal rate, seat height, and foot position. From these variables the magnitudes and directions of the resulting force were determined.

Power outputs of 0, 120, and 240 watts were obtained using a constant braking weight of 2 kg at four different pedalling rates of 40, 60, 80, and 100 RPM. Seat height was described as three different positions: "low" being 102% of the distance between the individual subject's ischial tuberosity and medial malleolus, "medium" being 113% of that measured distance, and "high" being 120%. Foot position was explained as being either an anterior position in which the ball of the foot was placed in the center of the pedal, or a posterior position in which the instep of the foot was placed in the center of the pedal. It is interesting to note that during this study, when one of the four variables was changed and studied, the other three remained unchanged. The authors stated that the resulting forces applied to the pedal, using all the variables in different and random order of selection, in every instance were directed downward, between zero and 160 degrees of crank angle. Between

160 and 360 degrees of crank angle, it was also found that the resulting force tended to have a backward direction. In conclusion, the authors claim from their results that pedal force is primarily due to action of the working muscles, and pedal forces which are inefficiently applied can cause inefficiency on muscular work. This inefficiency in muscular work would cause an increased amount of energy to be wasted. Therefore, changes in the efficiency of applied pedal force causes changes in oxygen consumption. The authors also conclude that these changes in muscular efficiency, as indicated by changes in oxygen consumption, are due to changes in power output and the position of the foot on the pedal.

## Electromyography

Bicycle ergometers are commonly used to prescribe exercise and to perform testing on patients in a hospital setting. For the purpose of research it is important to study the electrical activity of the muscles involved in riding a stationary bicycle. The knowledge gained from this type of research is important to physical therapists as well as physicians because it provides an understanding of the roles of specific muscles during pedalling this type of ergometer. The magnitude (sometimes referred to as amplitude) of the electrical activity of the working muscles is directly measured during exercise and the signal has been shown to increase with increasing work rates (Goto, Toyoshima, & Hoshikawa, 1975; Houtz & Fischer, 1959; Mohr, Allison, & Patterson, 1981).

When studying the electrical activity of skeletal muscles, surface electromyography (EMG) is often used. Surface electrodes are placed on the skin, directly above the working muscles.

Mohr, Allison, and Patterson (1981) reported a study which compared the EMG activity of six lower extremity muscles in six healthy male subjects while pedalling on a bicycle ergometer. Many variables were tested including changes in work rate, pedalling rates, flywheels of different weights, with and without toe clips, and pedalling from both a seated and a standing position.

The authors of this study found that all six muscles observed using EMG (gluteus maximus, biceps femoris, rectus femoris, vastus lateralis, gastrocnemius, and tibialis anterior) were all shown to be active at a work rate greater than 300 kpm/min. The amplitude of the EMG signals increased with each work rate increase. No significant differences were found in the EMG activity of the muscles when pedalling against a light or a heavy flywheel. Changes in the EMG signal amplitude with increasing pedalling rates were found to be quite variable.

Houtz and Fischer (1959) performed a study to determine which lower limb muscles participate in exercise on a stationary bicycle ergometer. The authors used surface electrodes to observe the EMG activity of 14 muscles. Of the 14 muscles observed, the muscles found to be essential for pedalling a stationary bicycle were tensor fascia latae, sartorius, quadriceps femoris, and tibialis anterior. Muscles found to produce minimal electrical activity were gluteus maximus, gluteus medius, sacrospinalis, and rectus abdominis. The authors also found that EMG activity intensified with either an increase in work rate or pedalling rate. However, the timing of the muscles remained orderly and coordinated with increases in work rate or pedalling rate.

A similar study was done by Goto, Toyoshima, and Hoshikawa (1975), in which they applied surface electrodes on the gluteus maximus, vastus lateralis, gastrocnemius, and tibialis anterior. The results from this study showed a linear relationship between EMG activity, pedalling rate, and the work rate in the vastus lateralis and gastrocnemius in subjects who pedaled with increasing work rates and pedalling rates. Curvilinear relationships were shown between EMG activity, pedalling rate, and work rate for the tibialis anterior and gluteus maximus muscles in subjects who pedaled with increasing work rates and pedalling rates.

Desipres (1974) studied the effect of saddle height and work rate on the pattern of EMG signals under the conditions of competitive road riding conditions, which were simulated on a treadmill. The muscular electrical activity was picked up by the use of surface electrodes on 12 different muscles. The author of this study found that increased saddle height led to earlier and longer duration of muscle electrical activity throughout each pedal cycle.

Tate and Shierman (1977) studied EMG activity in the biceps femoris, rectus femoris, gastrocnemius, and tibialis anterior while pedalling with and without toe clips. The authors found that all the muscles were electrically active for a longer duration throughout the pedal cycle with toe clips than without toe clips.

In a study done by Ericson, Nisell, Arborelius, and Ekholm (1985) 11 subjects rode a bicycle ergometer at different work rates, pedalling rates, saddle heights, and pedal foot positions. The authors found that the vastus medialis and lateralis, gastrocnemius, and the soleus muscles were the most electrically active muscles during exercise on the bicycle ergometer. An increase in work rate significantly increased the mean maximum electrical activity in all muscles investigated. An increase in pedalling rate resulted in an increase in the electrical activity of the gluteus maximus and medius, vastus medialis, medial hamstring, gastrocnemius, and soleus muscles. Muscular electrical activity was also increased in the gluteus medius, medial hamstring, and gastrocnemius when saddle height was increased.

Results from this study were compared to earlier studies of EMG activity and duration during cycling (Houtz & Fischer, 1959; McLeod & Blackburn, 1980; Suzuki, Watanabe, & Homma, 1982) and no major contradictions in the muscular electrical activity patterns were found.

## Rating of Perceived Exertion

Rating of perceived exertion (RPE) has become an increasingly important variable that is measured during physiological research testing. Researchers use this variable to investigate the relationship between work intensity and many other factors such as heart rate (HR), oxygen consumption ($VO_2$), cardiac output (Q), and ventilation ($V_E$). Perceived exertion was defined by Morgan (1973) as the subject's subjective rating of the level of the work intensity being performed. Morgan also stated that this estimate of work intensity is based primarily on the actual amount of work being done during exercise, which is itself related directly to the metabolic cost of the exercise and the actual work produced during that exercise bout. RPE is a valuable tool in the exercise physiology setting and is often considered more important than many variables that are tested because RPE does not measure what the individual is doing, but what the individual thinks he is doing.

Borg (1973) introduced a rating scale of perceived exertion. The first scale was a 21 point scale which resulted in high correlations (between .80 and .90) with heart rate when ratings of perceived exertion were obtained. Later this scale was changed for the purpose of increasing the linearity between heart rate (and work rate) and rating of perceived exertion.

Pandolf and Noble (1973) tested 15 male subjects who were in high physical condition. These subjects rode on a bicycle ergometer at pedalling rates of 40, 60, and 80 RPM at power outputs approximately equivalent at the levels of 550, 775, and 1075 kpm/min for the respective pedal rates. Oxygen consumption was recorded and found not to be significantly different for each pedalling rate at the equivalent power outputs. The ratings of perceived exertion at the equivalent power outputs for the pedalling rates of 60 and 80 RPM were found to be negatively related to those pedalling rates. The authors found a difference in responses of RPE at the higher power outputs for each pedalling rate performed. A linear relationship was found between oxygen consumption and power output, between perceived exertion and power output, as well as between perceived exertion and heart rate.

The main results and findings in this study by Pandolf and Noble indicated that RPE could be used as an important determination of local muscular stress and discomfort. The authors stated that if it is possible for an individual riding on a bicycle ergometer to perceive the amount of force required of the muscle to overcome the resistance produced during pedalling, then the findings of the authors are of no surprise that a high pedalling rate of 80 RPM or greater is subjectively preferred for the majority of power outputs.

In a similar study reported one year later by Stamford and Noble (1974) ten subjects who were in high physical condition rode on a bicycle ergometer at pedalling rates of 40, 60, and 80 RPM but at a constant power output of 960 kpm/min. The authors found a significant difference in the relationship of RPE to each pedalling rate. This relationship was found to be a non-linear relationship. The pedalling rate of 60 RPM was perceived by the subjects as the rate that was least stressful on them. The authors stated that their results of a non-linear relationship between RPE and pedalling rate were in conflict with those found by the study done earlier by Pandolf and Noble (1973) in which RPE was found to be negatively related to pedalling rate. The authors stated that their results of a non-linear relationship between RPE and pedalling rate as compared to other findings was "open to speculation" and that any significant differences found in responses of RPE are thought to be a result of the exertion produced by the exercising limbs of the subjects and how hard those subjects perceive that exertion to be in each individual situation.

Lollgen, Ulmer, Gross, Wilbert, and Nieding (1975) found that when using a rating of perceived exertion scale, the main influence on the RPE of the subject is the level of the pedalling rate. The authors stated this to be the main factor. It was also found that the greater the mass of the flywheel while riding a bicycle ergometer, the lower the level of perceived exertion reported by the subject. A lower level of perceived exertion was also reported by the subjects in this study when pedalling at higher rates, especially at a pedal rate of 100 RPM or greater.

Lollgen, Ulmer, and Nieding (1977) investigated the relationship of RPE and pedalling rate. The authors found that as pedalling rate increased (while pedalling at a constant work rate) the perceived exertion of the subjects decreased. The authors concluded that the rating of perceived exertion demonstrated a closer relationship with work rate than with heart rate and this was determined to be the result of the physical stress perceived by the subjects rather than the actual physiological stress perceived during exercise.

## Isokinetic versus Isotonic Exercise on a Bicycle Ergometer

Literature found and reviewed for this section was very limited. The following research was found only in abstract form and specific information from these studies was also limited.

Goodenday, Naylor, Harvey, and Perrine (1973) investigated a new form of exercise which was described as being neither isometric nor isotonic. This new form of exercise, isokinetic exercise, was studied to determine its potential application for use in a cardiac rehabilitation program. The authors described this new form of exercise as one that consists of a rhythmic type of pressure being forced against an accommodative type of resistance. Normal subjects aged 25 through 50 were tested on the isokinetic prototype and on an isotonic bicycle ergometer with work rates being the same for both. The authors found that there was no difference in oxygen consumption, heart rate, or arterial blood pressure for exercise on these two different ergometers. The authors concluded that isokinetic exercise creates no greater cardiovascular stress than the commonly used isotonic bicycle ergometer. The authors also concluded that since the isokinetic device provides increased flexibility in exercise loading, this type of exercise may be promising for patients with cardiovascular disease.

Goodenday, Naylor, Hill, and Harvey (1973) also investigated the effect of a wide range of speed-force combinations which produced the same measured work rate on the prototype isokinetic device. At constant work rates, heart rate varied inversely with speed. Blood pressure response varied inversely with speed and directly with force at low work rates. These investigators concluded that isokinetic work offered greater flexibility than fixed-resistance loading (isotonic) and therefore may have clinical training applications.

Nielsen (1982) initiated an on-going research project which was based upon physiological responses to isokinetic versus isotonic cycling exercise. In his report, Nielsen states that there is a considerable lack of research in this area. There are a great number of references cited in the product literature provided by the manufacturer. However, of those cited references, there were no studies which have investigated the specific physiological effects of exercise on the Fitron.

Nielsen (1982) tested 20 subjects on each bicycle ergometer for the various cardiovascular responses of oxygen consumption, heart rate, blood pressure, and myocardial oxygen consumption during exercise at a steady-state. Work rates for submaximal levels (300-1000 kpm/min) and pedalling rates (30, 45, 60, 75, and 90 RPM) were chosen. Results of this study revealed that oxygen consumption, heart rate, and systolic blood pressure were all significantly greater for isokinetic versus isotonic cycling exercise.

Nielsen and Ahrens (1983) did a comparison study using the Fitron bicycle ergometer, which provides an isokinetic type of exercise and a Monark bicycle ergometer, which provides an isotonic type of exercise. Ten males and ten females rode each of these ergometers at a constant work rate of 600 kpm/min while pedalling at different pedalling rates which were pre-selected at 30, 45, 60, 75, and 90 RPM. Energy cost was determined by measuring the oxygen consumption of each subject while riding the two different bicycle ergometers. Results of this study indicated that oxygen consumption, when exercising at a work rate of 600 kpm/min, was significantly greater for isokinetic versus isotonic cycling. The authors also found a significant difference in oxygen consumption between the two bikes for the five different pedalling rates. The pedalling rate of 60 RPM was found to result in the lowest energy cost in terms of oxygen consumption, and pedalling rates above or below 60 RPM were found to produce an increase in oxygen consumption.

Nielsen, Kispert, and Ahrens (1983) compared cardiovascular responses of subjects when riding an isokinetic versus an isotonic bicycle ergometer. Subjects rode both bikes at a constant work rate of 600 kpm/min at five different pre-selected pedalling rates of 30, 45, 60, 75, and 90 RPM. The authors found significant differences in heart rate and blood pressure and these differences were found to be higher for the isokinetic type of exercise. The authors stated that these results are of importance due to the fact that isokinetic cycling produces increased levels of muscle tension which can in turn produce high levels of heart rate and blood pressure. Production of high levels of heart rate and blood pressure by the isokinetic bicycle can be an advantage in that it provides the potential for a training effect that would be greater than that provided by isotonic cycling. However, someone who is known to have cardiovascular disease is at a greater risk when riding the isokinetic bike as opposed to riding the isotonic bike because of the high levels of heart rate and blood pressure produced when exercising on the isokinetic bicycle ergometer.

## Summary

Many factors have been shown to effect energy cost, relative efficiency, and other various physiological and cardiovascular responses while exercising on an isotonic type of bicycle ergometer. More research needs to be done to investigate these factors and responses utilizing a bicycle ergometer which provides an isokinetic type of exercise. Very little has been done with comparison of isokinetic versus isotonic exercise performed on a bicycle ergometer. This type of research is desperately needed in order to understand the effects of isokinetic exercise and to know when and if this type of exercise should be used in fitness programs where apparently healthy individuals are exercising, or even in a cardiac rehabilitation setting where patients in this type of program would be exercising.

# CHAPTER 3

## Methodology

In fitness programs where apparently healthy individuals are exercising, or even in a cardiac rehabilitation setting where patients in this type of program would be exercising, often two different bicycle ergometers are used. Most commonly used is the standard Monark bicycle ergometer. This ergometer has been used for many years by exercise physiologists as a means to test and prescribe exercise. However, another type of bicycle ergometer, the Fitron, has become an increasingly familiar name in the realm of fitness, rehabilitation, and therapy programs.

The focus of this study was to investigate the relative efficiency of the subjects on these two types of bicycle ergometers, the Monark and Fitron, by measuring oxygen consumption. The subjects exercised on both ergometers at a specifically prescribed work rate and at a constant pedal rate of 60 RPM to determine their metabolic response.

The description of the subjects, the testing procedures, and the analysis of the data collected will be explained in this chapter.

### Subjects

Seventeen male subjects ages 42-77 years, volunteered to offer their time and effort for this study. Twelve of the subjects were apparently healthy males who are members of the Eastern Illinois University Adult Fitness Program. The remaining five subjects were apparently healthy males who exercise on a regular basis and who teach either in the Physical Education Department or in other departments of Eastern Illinois University. Physical characteristics of the subjects are presented in Table 1.

## Experimental Design

Each of the seventeen male subjects performed two tests, one on the Fitron bicycle ergometer and one on the Monark bicycle ergometer. Each test was a submaximal test in which the subject rode the bike until a steady-state in heart rate and oxygen consumption was reached. The work rate was determined for each subject according to records of exercise heart rate response from current participation in the Adult Fitness Program at Eastern Illinois University. Those subjects who were not current participants in the Adult Fitness Program were asked at what heart rate level they train at on a regular basis. The work rate for each individual was chosen to match his normal training heart rate.

The sequence of bikes used and tests performed was determined at random for each subject. The heart rate was continuously monitored during both tests and between the first and second test to determine that the subject had recovered before beginning the second test. Oxygen

Table 1

Physical Characteristics of the Subjects

| Subject | Age (yr.mo) | Weight (kg) | Height (cm) | Resting HR (bpm) |
|---|---|---|---|---|
| 01 | 72.10 | 85.6 | 179.07 | 70 |
| 02 | 46.10 | 78.2 | 180.34 | 68 |
| 03 | 50.03 | 76.9 | 185.42 | 64 |
| 04 | 42.02 | 75.4 | 175.26 | 48 |
| 05 | 68.05 | 74.3 | 171.45 | 60 |
| 06 | 70.08 | 76.2 | 170.18 | 68 |
| 07 | 77.06 | 68.2 | 170.18 | 72 |
| 08 | 61.11 | 76.4 | 175.26 | 68 |
| 09 | 67.10 | 69.5 | 179.07 | 56 |
| 10 | 49.05 | 98.2 | 173.99 | 60 |
| 11 | 47.01 | 73.0 | 182.88 | 64 |
| 12 | 46.04 | 78.0 | 185.42 | 68 |
| 13 | 52.11 | 85.2 | 175.26 | 96 |
| 14 | 55.05 | 71.3 | 181.61 | 88 |
| 15 | 45.07 | 77.3 | 177.80 | 49 |
| 16 | 51.06 | 90.2 | 186.69 | 45 |
| 17 | 65.06 | 85.2 | 175.26 | 81 |
| Mean | 57.02 | 78.77 | 177.95 | 66.18 |
| SD | 11.03 | 7.80 | 5.25 | 13.49 |

consumption, heart rate, and the duration electrical activity (electromyograms) of four muscles of the right leg of each subject were monitored during all tests.

## Data Collection Procedures

Before coming to the Human Performance Laboratory for the scheduled testing session, each subject was given an introductory letter (Appendix A) in which the entire purpose and procedures of the study were described and explained.

Upon arrival at the Human Performance Laboratory, prior to the beginning of the actual testing session, each subject was given a brief verbal description of the testing procedures to re-familiarize him with the study. The subject then read the Informed Consent Form for Participation in a Research Project (Appendix B) and after all questions had been answered, the subject signed this form indicating he was willing to participate in the study. Resting heart rate and blood pressure was then taken and recorded. Subjects were weighed in kilograms and height was recorded in centimeters. A Vantage Performance Heart Rate Monitor was placed on the chest and was used to monitor the heart rate during and between the two tests performed.

To prepare the subject for the electromyographic recordings during the two tests, four muscles of the right leg were individually located and prepared. The four muscles studied were: 1) vastus lateralis, 2) biceps femoris, 3) tibialis anterior and 4) gastrocnemius. Each of these four muscles were palpated one at a time. The area where the electrodes were to be placed was shaved free of hair, slightly abraded with fine sandpaper (this was done to remove the top layer of dead skin cells which decreases the skin resistance for the electrodes). The area was then wiped with alcohol to clean away any remaining dead skin cells and any dirt and oil which may have remained in the area following the skin abrasion. Three electrodes were then placed on the prepared area of skin, two on the muscle in the area prepared and one away from the area (the ground electrode). The two main electrodes were carefully placed and inter-electrode distance was consistently measured to be 2 cm for all four muscles being prepared and recorded. When preparation of the four muscles for the electromyographic recordings was completed, the subject was then taken into the testing area of the lab.

Once in the testing area, saddle height was adjusted for each individual subject. The bicycle ergometer seat was adjusted so that almost complete extension of the subject's leg occurred when the pedal was in the down position, and so that the subject felt comfortable when pedalling. When testing on the Monark bike, pedal rate was set for the subject at 60 RPM by the use of a metronome, and adjustment of the tension to set brake load was done as the subject began to pedal. The Monark ergometer was calibrated using weights prior to the testing session. When testing on the

Fitron, desired work rate in kpm/min was set by rotating the faceplate of the gauge to align the red line with the level of workload desired. The pedal rate of 60 RPM was pre-set and was held constant as the subject performed the test. Calibration of the RPM setting was performed prior to the start of testing. The subject would then begin to pedal the Fitron, which caused the black needle of the faceplate to move toward the red line until black needle and red line were in exactly the same position on the gauge. This indicated that the subject was pedalling at the desired RPM for the work rate chosen for that particular test.

Before the actual testing procedures began, the subject was allowed a five minute warm-up while the physiograph used for the electromyographic recordings (MIL-IV-P Physiograph by Narco Biosystems provided by the Eastern Illinois University Zoology Department) was adjusted as to sensitivity and quality of recording. The subject was then prepared for the oxygen consumption recordings by the positioning of a head harness and a Hans-Rudolph respiratory valve. The mouthpiece was adjusted so that it was comfortable when in place and a nose clip was placed on the nose to insure that all the air ventilated would enter the on-line system.

The subject then began pedalling and the test was started. Pedal count was recorded each minute and the heart rate was recorded every 30 seconds. When the first 30 seconds of the test were completed, the electromyographic recordings were taken. The starting points and ending points for the duration of electrical activity of the four right leg muscles during exercise were taken directly from these chart EMG recordings. Heart rate and oxygen consumption were continuously monitored until the subject was found to have reached a steady-state. The investigators found the subjects to have reached a steady-state when their exercise heart rates were within 2-3 beats or less of each other after a minimum of two consecutive one minute stages. Blood pressure was then taken and recorded. At this point the subject was asked to view a Borg's Scale of Perceived Exertion Chart (Appendix E) and determine how difficult he perceived the exercise to be by providing the appropriate number from the scale. The subject had then completed the first test and was helped off of the bike. The subject sat down in a chair away from the two bikes and rested to allow the heart rate to recover before the second test would begin.

During the two tests, samples of expired air were drawn through an S-3A oxygen analyzer and a CD-3A carbon dioxide analyzer, both manufactured by Applied Electrochemistry, to determine the fractions of oxygen and carbon dioxide present in the expired air. Ventilation volumes, as measured by a Rayfield Air Meter, were corrected to STPD (standard temperature, pressure and dry) and oxygen consumption per minute was calculated using a Rayfield computer program (REP-200C Software for Apple II Plus, Rayfield Equipment, Ltd.).

## Statistical Analysis

The individual data collected was recorded for statistical treatment. A t-test for dependent observations was used to determine the significance of difference between the mean oxygen consumption, heart rate, blood pressure, rating of perceived exertion, average pedal count, and electromyographic activity. The 0.05 level of significance was chosen to denote statistical difference in the study.

Chapter 4

# Analysis of Data

This study was designed to investigate any difference in the relative efficiency of 17 male subjects when exercising on a Fitron bicycle ergometer as compared to a Monark bicycle ergometer ridden at the same work rate. This efficiency was determined from levels of oxygen consumption, exercise heart rates, ratings of perceived exertion, blood pressures, and the electromyographic recordings of four right leg muscles during exercise bouts on the two different bicycle ergometers.

## Findings

### Descriptive Statistics

Seventeen male volunteers participated in this study. Their individual data may be found in Table 1 and Appendices F, G, H, I, J, and K. This individual data is presented as descriptive data of the subjects and their performances during testing.

### Age, Weight, and Height

All subjects were between the ages of 42 and 78 years. The mean age was 57.02 years with a standard deviation of 11.03 years. Subjects were weighed on their test day just prior to beginning the testing session. Mean body weight was 78.77 kilograms with a standard deviation of 7.8

kilograms. All subjects were 170.18 centimeters or taller with the mean height being 177.95 centimeters and a standard deviation of 5.25 centimeters (Table 1).

Resting Heart Rate

Resting heart rates were recorded as indicators to determine when subjects had recovered after completing the first test. Subjects were allowed to recover to within ten beats of their resting heart rate. All resting heart rates were recorded from a Vantage Performance Heart Rate Monitor. The mean resting heart rate was 66.18 beats per minute with a standard deviation of 13.49 beats per minute (Table 1).

Work Rate and Average Pedal Rate

The range of average pedal rates for tests performed on the Monark bicycle ergometer was 59-64 RPM and 55-64 RPM for tests performed on the Fitron bicycle ergometer (Appendix H). The mean value for average pedal rate was 62 RPM with a standard deviation of 1.28 RPM for tests performed on the Monark bicycle ergometer (Table 2). The mean value for average pedal rate was also found to be 62 RPM with a standard deviation of 2.69 RPM for tests performed on the Fitron bicycle ergometer. A t-test performed on the average pedal rates at the various work rates, revealed no significant difference between the two bicycle ergometers (Table 2).

Table 2

Means and Standard Deviations of Average Pedal Count
Monark versus Fitron

| | Average Pedal Count |
|---|---|
| Monark | |
| Mean | 62.0 |
| SD | 1.28 |
| Fitron | |
| Mean | 62.0 |
| SD | 2.69 |
| Difference | |
| Mean | 0.00 |
| SD | 3.02 |
| SE-Mean | 0.73 |
| t-value | 0.00 |
| t: 95%/16df | 2.12 |
| Ho: Diff= 0 | Accept |

Oxygen Consumption

Oxygen consumption was monitored throughout both tests. The mean value for oxygen consumption was taken from the steady-state data and was found to be 2.11 liters per minute with a standard deviation of 0.53 liters per minute for tests performed on the Monark bicycle ergometer (Table 3). The mean value for oxygen consumption while testing on the Fitron bicycle ergometer was 1.88 liters per minute with a standard deviation of 0.59 liters per minute (Table 3). A t-test revealed a statistically significant difference in oxygen consumption between tests performed on the Monark and Fitron bicycle ergometers (Table 3).

Exercise Heart Rate

Heart rate was monitored during and between both tests using the Vantage Performance Heart Rate Monitor. Test rides on the Monark bicycle ergometer resulted in a mean steady-state heart rate value of 131.0 beats per minute with a standard deviation of 11.88 beats per minute (Table 3). Test rides on the Fitron bicycle ergometer resulted in a mean steady-state heart rate value of 123.94 beats per minute with a standard deviation of 13.37 beats per minute (Table 3). A t-test revealed a statistically significant difference in the steady-state heart rates between tests performed on the Monark and Fitron bicycle ergometers (Table 3).

Table 3

Means and Standard Deviations
$VO_2$, Heart Rate, Blood Pressure and RPE
Monark versus Fitron

| | $VO_2$ (l/min) | Heart Rate (bpm) | SBP / DBP (mmHg) | RPE |
|---|---|---|---|---|
| MONARK | | | | |
| Mean | 2.11 | 131.00 | 172.94 / 81.65 | 12.88 |
| SD | 0.53 | 11.88 | 19.13 / 8.04 | 1.22 |
| FITRON | | | | |
| Mean | 1.88 | 123.94 | 161.65 / 81.29 | 11.94 |
| SD | 0.59 | 13.37 | 20.21 / 7.84 | 1.09 |
| DIFFERENCE | | | | |
| Mean | 0.228 | 7.059 | 11.294 / 0.353 | 0.941 |
| SD | 0.108 | 5.921 | 15.826 / 5.396 | 1.435 |
| SE-Mean | 0.026 | 1.436 | 3.838 / 1.309 | 0.348 |
| t-value | 8.736 | 4.915 | 2.942 / 0.270 | 2.704 |
| t:95%/16df | 2.120 | 2.120 | 2.120 / 2.120 | 2.120 |
| Ho: Diff=0 | Reject | Reject | Reject / Accept | Reject |

Systolic and Diastolic Blood Pressure

Means and standard deviations were calculated for systolic and diastolic blood pressure. This data was obtained and recorded during the last 30 seconds of each test ride once a steady-state was determined to have been reached by the subject. The mean systolic blood pressure for rides on the Monark bicycle ergometer was 172.94 mmHg with a standard deviation of 19.13 mmHg (Table 3). The mean diastolic blood pressure for rides on the Monark bicycle ergometer was 81.65 mmHg with a standard deviation of 8.04 mmHg (Table 3).

The mean systolic blood pressure for rides on the Fitron bicycle ergometer was 161.65 mmHg with a standard deviation of 20.21 mmHg (Table 3). The mean diastolic blood pressure for rides on the Fitron bicycle ergometer was 81.29 mmHg with a standard deviation of 7.84 mmHg (Table 3). A t-test revealed a statistically significant difference in systolic blood pressure between tests performed on the Monark and Fitron bicycle ergometers. There was no statistically significant difference found in diastolic blood pressure between tests performed on the Monark and Fitron bicycle ergometers (Table 3).

Rating of Perceived Exertion

Borg's Scale (Appendix E) was provided for and used by the subjects during each test. RPE was recorded during the last 30 seconds of each test immediately following blood pressure measurement (Appendix I). The mean RPE for rides on the Monark bicycle ergometer was 12.94 with a standard deviation of 1.23 (Table 3). The mean RPE for rides on the Fitron bicycle ergometer was 11.88 with a standard deviation of 1.09 (Table 3). A t-test revealed a statistically significant difference in RPE between tests performed on the Monark and Fitron bicycle ergometers (Table 3).

Electromyography

The duration of electrical activity of four muscles of the right leg was recorded during both tests. Electromyographic recordings were used to determine the sequence and the duration of electrical activity of those muscles during one pedal cycle on each bike. These recordings were taken during the first 30 seconds of each test. The muscles studied were: 1) vastus lateralis, 2) biceps femoris, 3) tibialis anterior, and 4) gastrocnemius. Individual EMG data is shown in Appendices J and K. Means and standard deviations were calculated for onset and termination of activity of each muscle. Each value represents the number of degrees out of a 360 degree circle where the straight down position of the right pedal and crank is represented by "0" degrees.

The mean values for onset of electrical activity for each of the muscles during tests performed on the Monark bicycle ergometer were 139.3, 148.7, 45.8, and 239.5 degrees respectively, with standard deviations of 12.7, 11.2, 56.7, and 43.7 degrees, respectively (Tables 4 & 5, Figure 1). The mean values for termination of electrical activity of each muscle during tests performed on the Monark bicycle ergometer were 300.5, 55.7, 178.5, and 62.9 degrees respectively, with standard deviations of 13.8, 53.3, 31.5, and 40.3 degrees, respectively (Tables 4 & 5, Figure 1).

The mean values for onset of electrical activity for each of the muscles during tests performed on the Fitron bicycle ergometer were 129.0, 153.9, 35.2, and 226.2 degrees respectively, with standard deviations of 11.5, 46.4, 46.9, and 53.4 degrees, respectively (Tables 4 & 6, Figure 2). The mean values for termination of electrical activity for each muscle during tests performed on the Fitron bicycle ergometer were 286.3, 37.7, 158.6, and 37.1 degrees respectively, with standard deviations of 11.2, 84.1, 26.5, and 46.5 degrees respectively (Tables 4 & 6, Figure 2). A t-test revealed a statistically significant difference in onset and termination of electrical activity of the vastus lateralis between tests performed on the Monark and Fitron bicycle ergometers. A statistically significant difference was also found for termination of electrical activity of the tibialis anterior and the gastrocnemius between tests performed on the Monark and Fitron bicycle ergometers. No statistically significant differences were found for either the onset or termination of electrical activity of the biceps femoris between tests performed on the Monark and

Table 4

Means and Standard Deviations of Measured Variables
Electromyographic Recordings of Four Right Leg Muscles

| | Vastus Lateralis | | Biceps Femoris | | Tibialis Anterior | | Gastrocnemius | |
|---|---|---|---|---|---|---|---|---|
| | Start | Finish | Start | Finish | Start | Finish | Start | Finish |
| Monark | | | | | | | | |
| Mean | 139.25 | 300.49 | 148.74 | 55.69 | 45.78 | 178.54 | 239.45 | 62.86 |
| SD | 12.73 | 13.80 | 11.18 | 53.31 | 56.68 | 31.50 | 43.69 | 40.29 |
| Fitron | | | | | | | | |
| Mean | 128.98 | 286.34 | 153.91 | 37.71 | 35.22 | 158.57 | 226.21 | 37.12 |
| SD | 11.45 | 11.20 | 46.38 | 84.10 | 46.89 | 26.47 | 53.44 | 46.45 |
| Difference | | | | | | | | |
| Mean | 10.27 | 14.15 | -5.17 | 17.98 | -10.56 | 19.97 | 13.24 | -25.74 |
| SD | 13.86 | 15.86 | 42.23 | 73.27 | 50.72 | 37.87 | 42.92 | 34.16 |
| SE-Mean | 3.362 | 3.847 | 10.243 | 17.771 | 12.302 | 9.185 | 10.410 | 8.285 |
| t-value | 3.055 | 3.678 | -0.505 | 1.012 | -0.858 | 2.174 | 1.272 | -3.107 |
| t: 95%/16 df | 2.120 | 2.120 | 2.120 | 2.120 | 2.120 | 2.120 | 2.120 | 2.120 |
| Ho: Diff = 0 | Reject | Reject | Accept | Accept | Accept | Reject | Accept | Reject |

Numbers represent degrees out of a 360-degree circle
"0" degrees represents the straight-down position for the right pedal and crank

Table 5

Mean Values for Onset, Termination, and Duration of EMG Activity
Monark Bicycle Ergometer

| | Onset | Termination | Duration |
|---|---|---|---|
| Vastus Lateralis | 139.3 | 300.5 | 161.2 |
| Biceps Femoris | 148.7 | 55.7 | 267.0 |
| Tibialis Anterior | 45.8 | 178.5 | 132.7 |
| Gastrocnemius | 239.5 | 62.9 | 183.4 |

Figure 1

Mean Onset, Termination, and Duration of EMG Activity
Monark Bicycle Ergometer
(right side view)

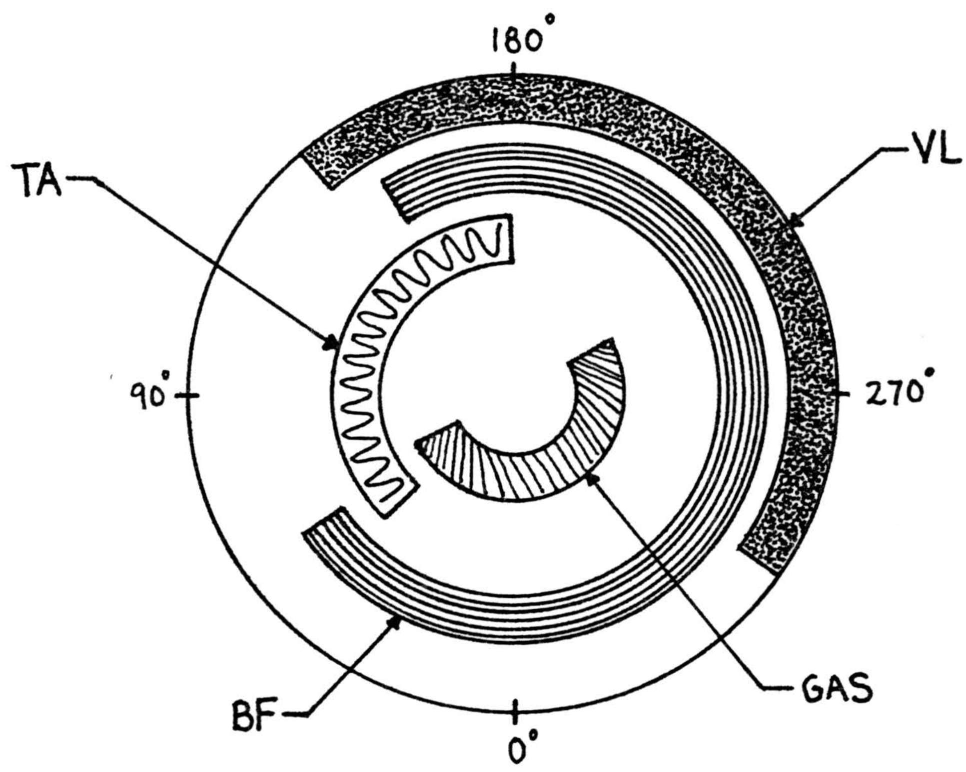


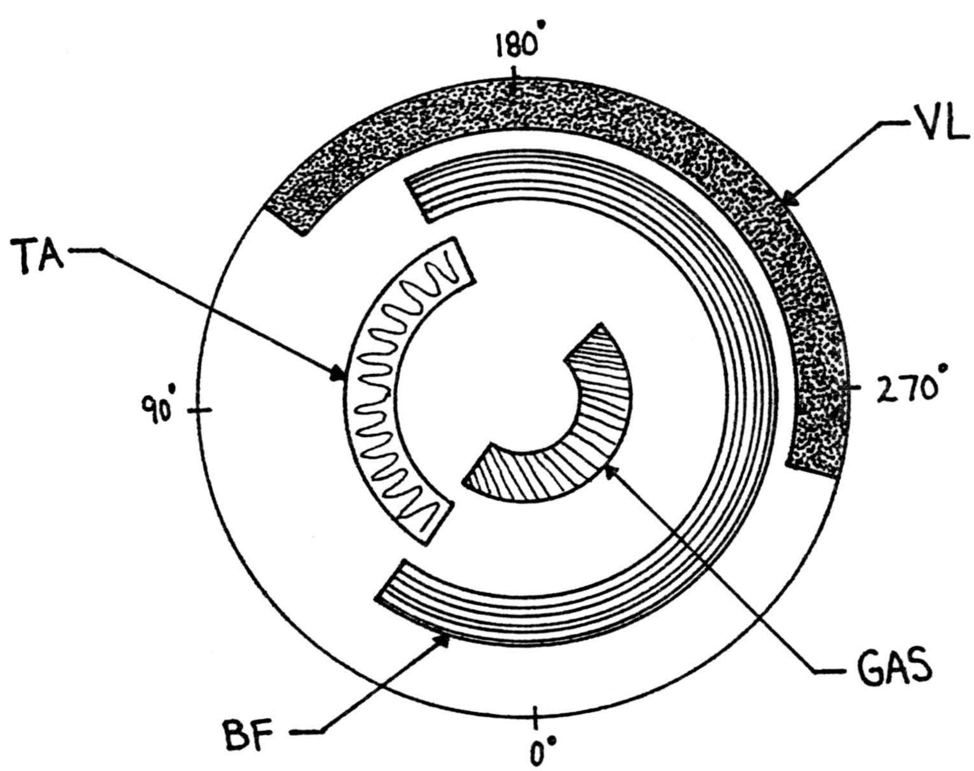
Table 6

Mean Values for Onset, Termination, and Duration
of EMG Activity
Fitron Bicycle Ergometer

| | | Onset | Termination | Duration |
|---|---|---|---|---|
| | Vastus Lateralis | 129.0 | 286.3 | 157.3 |
| | Biceps Femoris | 153.9 | 37.7 | 243.8 |
| | Tibialis Anterior | 35.2 | 158.6 | 123.4 |
| | Gastrocnemius | 226.2 | 37.1 | 170.9 |

Figure 2

Mean Onset, Termination, and Duration of EMG Activity
Fitron Bicycle Ergometer
(right side view)



Fitron bicycle ergometers. No statistically significant difference was found for the onset of electrical activity for the gastrocnemius between tests performed on the Monark and Fitron bicycle ergometers (Table 4).

The mean values for total duration of electrical activity in degrees for each of the four muscles during tests performed on the Monark bicycle ergometer were 161.2, 267.0, 132.7, and 183.4 degrees respectively, with standard deviations of 16.3, 50.0, 70.1, and 65.5 degrees, respectively (Table 7, Figure 1). The mean values for total duration of electrical activity in degrees for each of the four muscles during tests performed on the Fitron bicycle ergometer were 157.3, 243.8, 123.4, and 170.9 degrees respectively, with standard deviations of 14.6, 67.0, 53.5, and 74.4 degrees, respectively (Table 7, Figure 2). A t-test revealed no statistically significant differences in total duration of electrical activity in any of the four muscles between tests performed on the Monark and Fitron bicycle ergometers (Table 7).

## Discussion

The review of related literature for this investigation revealed a very limited number of studies available which compared isotonic and isokinetic exercise on a bicycle ergometer. The majority of the literature reviewed focused on studies performed using only the Monark bicycle ergometer.

Table 7

Means and Standard Deviations of Total Degrees Active
Monark versus Fitron

| | Vastus Lateralis | Biceps Femoris | Tibialis Anterior | Gastrocnemius |
|---|---|---|---|---|
| Monark | | | | |
| Mean | 161.20 | 267.00 | 132.70 | 183.40 |
| SD | 16.31 | 50.01 | 70.08 | 65.52 |
| Fitron | | | | |
| Mean | 157.30 | 243.80 | 123.40 | 170.90 |
| SD | 14.61 | 67.02 | 53.50 | 74.43 |
| Difference | | | | |
| Mean | 3.90 | 23.20 | 9.30 | 12.50 |
| SD | 15.16 | 62.20 | 65.80 | 51.70 |
| SE-Mean | 3.677 | 15.086 | 15.959 | 12.539 |
| t-value | 1.061 | 1.538 | 0.583 | 0.997 |
| t: 95%/16 df | 2.120 | 2.120 | 2.120 | 2.120 |
| Ho: Diff = 0 | Accept | Accept | Accept | Accept |

Numbers represent degrees out of a 360-degree circle
"0" degrees represents the straight-down position for the right pedal and crank

When an individual exercises on an isokinetic bicycle ergometer, such as the Fitron, increased levels of muscle tension are produced which can in turn produce high levels of heart rate and blood pressure (Nielsen,1982). Nielsen and Ahrens (1983) investigated this concept of isokinetic exercise on a bicycle ergometer and compared it to isotonic exercise performed on a Monark bicycle ergometer. Results of this study indicated that oxygen consumption, when exercising at a work rate of 600 kpm/min, was significantly higher for isokinetic versus isotonic cycling.

In the present investigation, oxygen consumption, heart rate, and blood pressure were all found to be significantly higher for isotonic exercise performed on the Monark bicycle ergometer. These findings conflict with the results found in a study reported by Nielsen (1982), Nielsen & Ahrens (1982), and Nielsen et al. (1983) which compared the Monark and Fitron bicycle ergometers.

The study reported by Nielsen (1982), Nielsen & Ahrens, (1983), and Nielsen et al. (1983) found significantly higher results for oxygen consumption, heart rate, and blood pressure when exercising on the isokinetic bicycle ergometer compared to exercise on the isotonic bicycle ergometer. From a physiological basis, isokinetic cycling exercise creates increased levels of muscle tension in comparison to isotonic cycling exercise (Nielsen, 1982). These levels in turn cause increased cardiovascular responses, even at submaximal levels (Nielsen, 1982; Nielsen & Ahrens, 1983; Nielsen et al., 1983).

Goodenday, Naylor, Harvey, and Perrine (1973) found no significant difference in oxygen consumption, heart rate, or arterial blood pressure for exercise on the isotonic versus the isokinetic ergometers. The investigators concluded that isokinetic exercise creates no greater cardiovascular stress than the commonly used isotonic bicycle ergometer.

A possibility exists in the present study that, despite a physiological basis which conflicts with the findings, the inability to calibrate the Fitron bicycle ergometer could have greatly affected the outcome of the data and the statistical analysis of the data in favor of isotonic cycling exercise. The researchers of the present investigation were unable to calibrate the Fitron as far as work rate precision. However, pedal rate was calibrated.

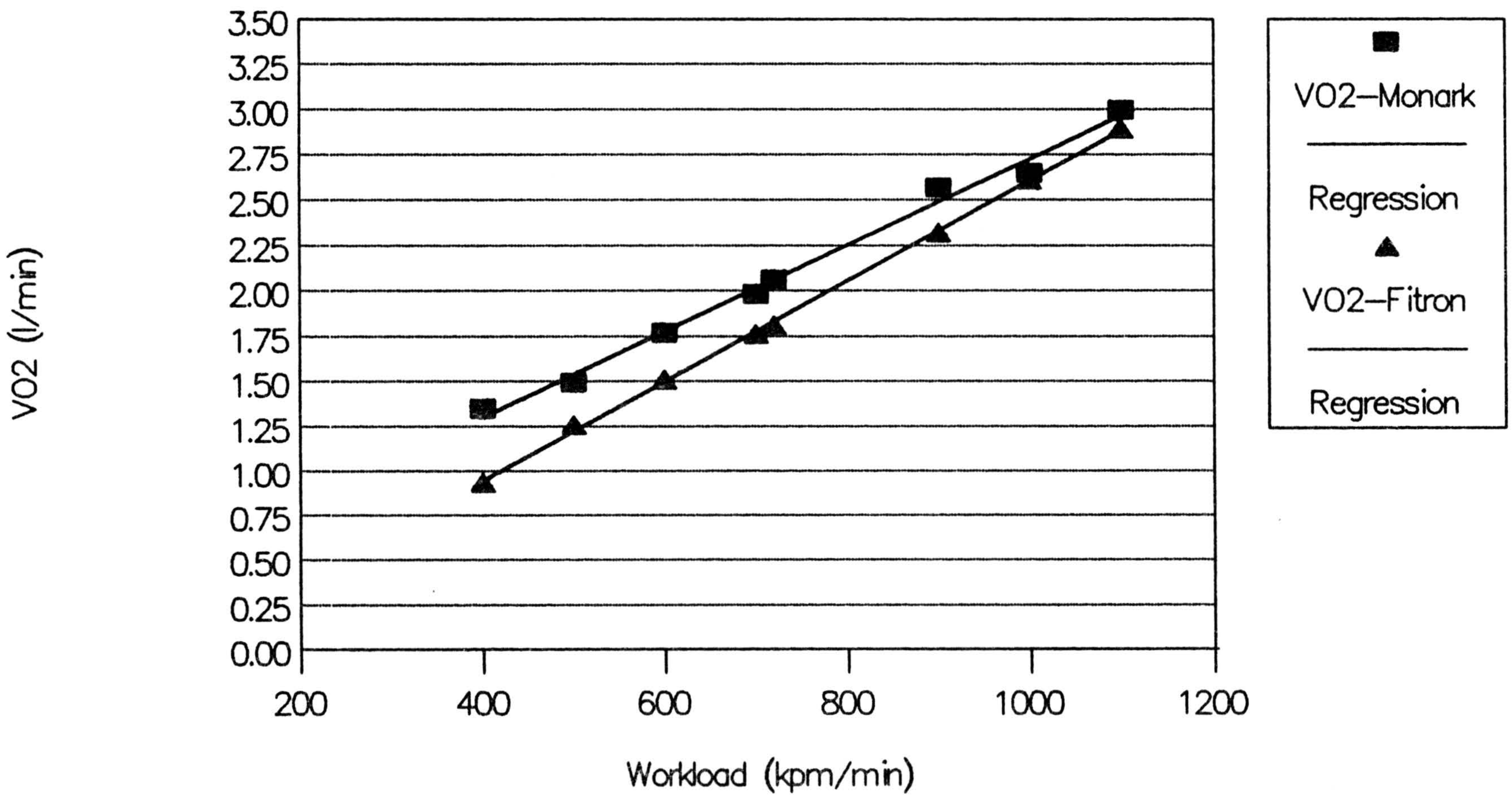
When subjects were tested on the Fitron bicycle ergometer, RPMs tended to show distinct variations at low work rates and high work rates versus the middle work rates. At the lower work rates (400 and 500 kpm/min) the subjects experienced great difficulty in maintaining the 60 RPM pedal rate. At these lower work rates the subjects consistently pedaled below the desired pedal rate of 60 RPM, even though the work rate setting was accurately maintained. At the higher work rates (720, 900, 1000, and 1100 kpm/min) the subjects also experienced difficulty in maintaining the

60 RPM pedal rate. At these higher work rates the subjects consistently pedaled above the desired pedal rate of 60 RPM although the work rate setting was maintained. When tests were performed with work rates in the middle range (600 and 700 kpm/min) subjects consistently pedaled at 60 RPM $\pm$ 1 RPM. There was a greater difference in mean pedal rates between bikes for subjects who tested at the low work rates and high work rates than those who tested in the middle work rates (Appendix H). A distinct possibility exists that the Fitron bicycle ergometer is inaccurate in determining work rate and keeping pedal rate constant at the low and high work rate settings. In Figure 3, average oxygen consumption versus work rate is shown. Average oxygen consumption for exercise on the Fitron bicycle ergometer at the low work rates is much less than exercise on the Monark bicycle ergometer. However, as work rate increases, the difference in average oxygen consumption between the two bikes decreases. The higher the work rate setting, the closer in efficiency these two different bicycle ergometers became (Figure 3).

In this study, no significant differences were found for duration of electrical activity and very few differences were found for onset and termination of electrical activity of the muscles studied between tests performed on the Monark and Fitron bicycle ergometers. Perhaps in future studies, a comparison of the intensity of electrical activity using

Figure 3

Avg VO2 vs Work Rate, Monark and Fitron



electromyographic recordings should be performed since isokinetic exercise should elicit increased muscle tension.

## Application

The purpose of this study was to determine any difference in relative efficiency of the subjects when riding a Fitron bicycle ergometer as compared to a Monark bicycle ergometer. This efficiency was determined from levels of oxygen consumption, exercise heart rates, ratings of perceived exertion, blood pressures, and electromyographic recordings of four right leg muscles during exercise bouts on the two different bicycle ergometers.

Use of the Fitron bicycle ergometer in fitness programs where apparently healthy individuals are exercising, or even in a cardiac rehabilitation setting where patients in this type of program would be exercising, could have a special impact on the individuals and patients who use it compared to those who use the Monark bicycle ergometer. As defined in Chapter 1, relative efficiency is said to be an indirect method of determining efficiency. A high relative efficiency can be correlated with a low oxygen consumption. Lower oxygen consumptions were found for all the subjects in this study when exercise was performed on the Fitron bicycle ergometer. This finding means that even though all subjects individually exercised at a comparable work rate on both ergometers, when these subjects exercised on the Fitron they were more efficient.

The subjects, who participated in this study, were asked to offer any comments about the two bicycle ergometers upon completion of their testing session. Of the 17 subjects, 12 of them preferred exercise on the Fitron bicycle ergometer and only five preferred exercise on the Monark bicycle ergometer. The subjects who preferred exercise on the Fitron bicycle ergometer stated various reasons why they preferred this type of bicycle ergometer. Many stated that they felt the Fitron was smoother and easier to ride compared to the Monark. The Fitron seemed to offer less resistance and was much more comfortable to exercise on. Those subjects who preferred the Monark bicycle ergometer stated that they felt the Fitron provided work against a stronger resistance. One subject preferred the Monark bicycle ergometer for the very reason that the Fitron bicycle ergometer seemed easier and offered less resistance. One subject state that the Fitron did not seem like as much of a workout as compared to the Monark. Another comment offered by a subject who preferred the Fitron bicycle ergometer was that the Monark bicycle ergometer has "pedal slap", and did not offer a steady pressure during pedalling as the Fitron bicycle ergometer did.

Based on the findings in this study, use of the Fitron bicycle ergometer in fitness programs where apparently healthy individuals are exercising, or even in a cardiac rehabilitation setting where patients in this type of program would be exercising, could have a special impact on the individuals and patients who use it compared to the Monark bicycle ergometer. Exercise physiologists can now apply this new knowledge by prescribing exercise in an entirely new way.

Individuals are able to ride on a Fitron more efficiently. Individuals will perceive a lower level of exertion on the Fitron due to the higher relative efficiency produced. As a result, longer bouts of exercise are able to be obtained. This is a very important motivational force. If individuals feel as if they can exercise at higher work rates for longer periods of time on the Fitron compared to the same work rate on the Monark, this could be the motivational factor that will continue to keep them active in a fitness or a rehabilitation program.

# Chapter 5

## Summary, Conclusions, Recommendations

### Summary

In this study, two types of bicycle ergometers were compared to determine which bicycle ergometer provides the most efficient workout in terms of the work accomplished divided by the energy expended to do that work. A difference between these two bicycle ergometers was expected because of the types of exercise they provide.

Bicycle ergometers are used extensively in exercise prescription for both cardiac rehabilitation patients and healthy individuals. There are many advantages to using this mode of exercise as compared to others. A major advantage is that work performed is specified and can be predetermined.

The Fitron, manufactured by Cybex, is a relatively new type of bicycle ergometer which operates on the principle of isokinetic exercise. An accommodating resistance is provided while the individual pedals at a constant, pre-selected speed.

The Monark bicycle ergometer is an isotonic device also used for training and therapy. This ergometer provides exercise and resistance using a large and heavy flywheel. Use of this type of resistance provides momentum which allows the user to maintain a smooth pedalling motion.

This study was conducted to determine which bicycle ergometer would be the preferred apparatus utilized in a cardiac rehabilitation setting.

Seventeen male subjects, ranging in age from 42 to 78 years, volunteered to participate in this study. Twelve of the subjects were apparently healthy males who are members of the Eastern Illinois University Adult Fitness Program. The remaining five subjects were apparently healthy males who exercise on a regular basis and who teach either in the Physical Education Department or in other departments of Eastern Illinois University.

Each of the 17 male subjects performed two tests, one on the Monark bicycle ergometer and one on the Fitron bicycle ergometer. Each test was a submaximal test in which the subject rode the bike until a steady-state in heart rate and oxygen consumption was reached. Work rate was determined for each subject according to records of exercise heart rate response from current participation in the Adult Fitness Program at Eastern Illinois University. Those subjects who were not current participants in the Adult Fitness Program were asked at what heart rate level they train at on a regular basis. The work rate for each individual was chosen to match his normal training heart rate.

The sequence of bikes used and tests performed was determined at random for each subject. Heart rate was continuously monitored during both tests. Heart rate was also monitored between the first test and second test to determine that the subject had recovered from the first test before beginning the second test. Oxygen consumption, heart rate, and the duration of electrical activity of four muscles of the right leg (electromyography) of each subject were monitored during all tests.

The cardiovascular responses of oxygen consumption, heart rate, blood pressure, and RPE were all found to be significantly higher for isotonic exercise on the Monark bicycle ergometer. The mean value for oxygen consumption for tests performed on the Monark bicycle ergometer was 2.11 liters per minute. The mean value for oxygen consumption for tests performed on the Fitron bicycle ergometer was 1.88 liters per minute. The mean value for heart rate for tests performed on the Monark bicycle ergometer was 131 beats per minute, while for tests performed on the Fitron bicycle ergometer mean heart rate was 123.94 beats per minute. Test rides on the Monark bicycle ergometer resulted in a mean systolic blood pressure of 172.94 mmHg. The mean diastolic blood pressure for rides on the Monark bicycle ergometer was 81.65 mmHg. Test rides on the Fitron bicycle ergometer resulted in a mean systolic blood pressure of 161.65 mmHg. The mean diastolic blood pressure for rides on the Fitron bicycle ergometer was 81.29 mmHg. The mean RPE for rides on the Monark bicycle ergometer was 12.94. The mean RPE for rides on the Fitron bicycle ergometer was 11.88. Only a few significant differences were found for the electromyographic recordings during the two tests. A statistically significant difference in the onset and termination of electrical activity for the vastus lateralis muscle during one pedal cycle was found between tests performed on the Monark and Fitron bicycle ergometers. A statistically significant difference was also found for termination of electrical activity of the tibialis anterior and gastrocnemius muscles between tests performed on the Monark and Fitron bicycle ergometers. No statistically significant differences were found for either the onset or termination of electrical activity of the biceps femoris muscle between tests performed on the Monark and Fitron bicycle ergometers. No statistically significant difference was found for the onset of electrical activity for the gastrocnemius muscle between tests performed on the Monark and Fitron bicycle ergometers. The mean values for total duration of electrical activity in degrees for each of the four muscles during tests performed on the Monark bicycle ergometer were 161.2 degrees for the vastus lateralis, 267.0 degrees for the biceps femoris, 132.7 degrees for the tibialis anterior, and 183.4 degrees for the gastrocnemius. The mean values for total duration of electrical activity in degrees for each of the four muscles during tests performed on the Fitron bicycle ergometer were 157.3, 243.8, 123.4, and 170.9 degrees, respectively. No statistically significant differences in total duration of electrical activity in degrees were found between tests performed on the Monark and the Fitron bicycle ergometers in any of the four muscles studied.

## Conclusions

Based on the findings of this study, it was concluded that:

1. There was a statistically significant difference ($p<.05$) in the mean values for oxygen consumption, heart rate, blood pressure, and rating of perceived exertion during exercise rides on the Monark and Fitron bicycle ergometers.
2. Exercise rides on the Fitron bicycle ergometer consistently produced lower values for oxygen consumption, heart rate, blood pressure, and rating of perceived exertion.
3. Subjects are considered to be more efficient physiologically when exercising on the Fitron bicycle ergometer as compared to exercising on the Monark bicycle ergometer in terms of oxygen consumption.

## Recommendations

Based on the findings of this study, the following recommendations appear warranted:

1. A similar study should be conducted with a larger sample.
2. A similar study should be conducted which includes women as subjects.
3. A similar study should be conducted in which the Fitron bicycle ergometer is very carefully calibrated to ensure the precision of the work rate being performed during exercise testing.
4. A similar study should be done comparing the intensity of EMG recordings since isokinetic exercise should elicit increased muscle tension.
5. A similar study should be done using actual cardiac patients under a strict supervised and monitored testing situation.

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Appendix A

EASTERN ILLINOIS UNIVERSITY
Charleston, Illinois 61920-3099

ADULT FITNESS AND CARDIAC REHABILITATION

College of H.P.E.R. Department of Physical Education (217) 581-3510

May 15, 1990

Dear Member of the EIU Adult Fitness Program:

I'm attempting to conduct a research project and I would like to use you as a subject for one hour some time within the next two to three weeks. I plan to have subjects perform a moderate to low level ride on two different stationary bikes in our Human Performance Lab (where you were screened for the AF Program). The two, eight minute rides will be no more taxing than your regular AF workout and you'll have at least 15 minutes between each ride.

We will be measuring your heart rate, blood pressure, oxygen consumption, perceived exertion and the electrical activity of selected leg muscles for the purpose of comparing the two different types of bicycle ergometers. All of tests are "non-invasive", so you can rest assured that there will be no discomfort for you.

Because time is of great importance, I would appreciate hearing from you within the next day or so. I'll be at the track and pool on Friday morning or you can call me at 345-1053. If I'm not home, just leave your message on my answering machine or tell my roommate. I hope you can help out with the project. Thank you in advance for considering this request.

Patrice Keil

Patrice Keil
Graduate Student in the Exercise Sciences

Dear Friend: Let me add that Patrice is a very capable researcher. I am excited about the project and as one of her faculty advisors, I can assure you that your participation will be very helpful for us and educational for you. I hope you can spare one hour to take part.

Thank you,

M. Thomas Woodall, Ph.D.
Program Director

for your life

Appendix B

Consent For Participation in a Research Project

I, ____________________________________, state that I
NAME OF VOLUNTEER

wish to participate in the research project conducted by Patrice Keil. The study involves approximately one hour of my time in the Human Performance Laboratory at Eastern Illinois University during which I will perform two submaximal tests, one on the Monark bicycle ergometer and one on the Fitron bicycle ergometer. During both of these submaximal tests the following will be continuously monitored:

1. Heart Rate - use of a heart rate monitor provided by the EIU Adult Fitness Program.
2. Blood Pressure
3. Oxygen Consumption - measuring how much oxygen your body uses from the air. This procedure will require you to breath through a mouthpiece.
4. Electromyography - use of a machine which will measure the electrical activity of four muscles in the right leg.

The risks of these procedures are those which follow any muscular exertion such as muscle fatigue, muscle soreness or stiffness and muscle strain. The bicycle ergometer tests may also cause temporary breathlessness. The preparation procedures for the electromyographic recordings will require that each small area where electrodes will be placed to be shaved free of hair, a light abrasion of the skin with fine sandpaper, followed by an alcohol wipe which will clean away any dirt and oil. I understand that this procedure is necessary to decrease skin resistance against the electrodes.

The results of these tests will remain confidential. Reports of this research project will indicate only group averages with no identification of individuals.

I have been informed that I am free to withdraw from this study at any time. Any questions that I may have concerning the study or the submaximal bicycle tests will be answered by Patrice Keil or Dr. Phyllis Croisant. I freely and voluntarily consent to participate in this study.

| | |
|---|---|
| ________________ DATE | ______________________________ SIGNATURE OF VOLUNTEER |
| ________________ DATE | ______________________________ SIGNATURE OF WITNESS |

# Appendix C

## Monark Data Sheet

Name ______________________________

Date ______________

Age (years/months) _________

Height (cm) _______ Weight (kg) ________

Resting HR ______ Resting BP ____/____

Medications ______________

| Minute | Heart Rate | Pedal Count |
|---|---|---|
| 1 / 1:30 | ____/____ | _______ |
| 2 / 2:30 | ____/____ | _______ |
| 3 / 3:30 | ____/____ | _______ |
| 4 / 4:30 | ____/____ | _______ |
| 5 / 5:30 | ____/____ | _______ |
| 6 / 6:30 | ____/____ | _______ |

| | Heart Rate | Pedal Count | Blood Pressure | RPE |
|---|---|---|---|---|
| STEADY STATE | _____ | _____ | ____/____ | ___ |
| | _____ | _____ | | |

Rest time between bike rides __________

WORK RATE ___________

Preferred bike for exercise ____________

Compare the two bikes ______________________________

______________________________________________

# Appendix D

## Fitron Data Sheet

Name ______________________________

Date ______________

Age (years/months) _________

Height (cm) ________ Weight (kg) _________

Resting HR _______ Resting BP _____/_____

Medications _______________

| Minute | Heart Rate | Pedal Count |
|---|---|---|
| 1 / 1:30 | _____/_____ | ________ |
| 2 / 2:30 | _____/_____ | ________ |
| 3 / 3:30 | _____/_____ | ________ |
| 4 / 4:30 | _____/_____ | ________ |
| 5 / 5:30 | _____/_____ | ________ |
| 6 / 6:30 | _____/_____ | ________ |

| | Heart Rate | Pedal Count | Blood Pressure | RPE |
|---|---|---|---|---|
| STEADY STATE | _____ | _____ | _____/_____ | ___ |
| | _____ | _____ | | |

Rest time between bike rides ___________

WORK RATE ____________

Preferred bike for exercise ______________

Compare the two bikes ________________________________

__________________________________________________

# Appendix E

## Borg's Rating of Perceived Exertion Scale

| | |
|---|---|
| 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 F

## Cardiovascular Responses to Isotonic Exercise on the Monark Bicycle Ergometer

| Subject | $VO_2$ (l/min) | Heart Rate (bpm) | Blood Pressure (mmHg) |
|---|---|---|---|
| 01 | 2.21 | 115 | 170/70 |
| 02 | 1.87 | 155 | 162/88 |
| 03 | 2.10 | 138 | 142/70 |
| 04 | 2.59 | 128 | 172/80 |
| 05 | 1.35 | 124 | 138/70 |
| 06 | 1.52 | 126 | 218/100 |
| 07 | 1.47 | 121 | 164/82 |
| 08 | 1.76 | 134 | 190/90 |
| 09 | 2.55 | 136 | 168/82 |
| 10 | 2.56 | 114 | 176/80 |
| 11 | 2.93 | 143 | 180/80 |
| 12 | 1.98 | 125 | 168/82 |
| 13 | 1.70 | 134 | 160/80 |
| 14 | 1.70 | 152 | 170/82 |
| 15 | 3.06 | 126 | 182/78 |
| 16 | 2.65 | 118 | 200/94 |
| 17 | 1.91 | 138 | 180/80 |
| Mean | 2.11 | 131 | 172.94 / 81.65 |
| SD | 0.53 | 11.88 | 19.13 / 8.04 |

# Appendix G

## Cardiovascular Responses to Isokinetic Exercise on the Fitron Bicycle Ergometer

| Subject | $VO_2$ (l/min) | Heart Rate (bpm) | Blood Pressure (mmHg) |
|---|---|---|---|
| 01 | 1.84 | 105 | 170/74 |
| 02 | 1.77 | 156 | 152/86 |
| 03 | 1.81 | 125 | 150/82 |
| 04 | 2.27 | 128 | 168/78 |
| 05 | 0.93 | 108 | 128/70 |
| 06 | 1.32 | 117 | 194/100 |
| 07 | 1.20 | 107 | 160/72 |
| 08 | 1.50 | 125 | 140/90 |
| 09 | 2.24 | 123 | 160/76 |
| 10 | 2.45 | 110 | 188/84 |
| 11 | 2.87 | 142 | 152/72 |
| 12 | 1.76 | 123 | 162/78 |
| 13 | 1.45 | 125 | 122/80 |
| 14 | 1.41 | 142 | 164/88 |
| 15 | 2.92 | 122 | 168/82 |
| 16 | 2.61 | 122 | 190/90 |
| 17 | 1.68 | 127 | 180/80 |
| Mean | 1.88 | 123.94 | 161.65 / 81.29 |
| SD | 0.59 | 13.37 | 20.21 / 7.84 |

# Appendix H

## Individual Work Rate and Average Pedal Count Monark versus Fitron

| Subject | Work Rate (kpm/min) | Average Pedal Count (RPM) Monark | Average Pedal Count (RPM) Fitron |
|---|---|---|---|
| 01 | 720 | 64 | 61 |
| 02 | 720 | 62 | 63 |
| 03 | 720 | 62 | 62 |
| 04 | 900 | 62 | 64 |
| 05 | 400 | 63 | 55 |
| 06 | 500 | 62 | 60 |
| 07 | 500 | 61 | 58 |
| 08 | 600 | 60 | 60 |
| 09 | 900 | 62 | 63 |
| 10 | 900 | 62 | 63 |
| 11 | 1100 | 60 | 65 |
| 12 | 700 | 63 | 62 |
| 13 | 600 | 59 | 60 |
| 14 | 600 | 62 | 61 |
| 15 | 1100 | 62 | 66 |
| 16 | 1000 | 61 | 64 |
| 17 | 600 | 60 | 60 |
| Mean | 738.8 | 62.0 | 62.0 |
| SD | 211.5 | 1.28 | 2.69 |

# Appendix I

## Individual Work Rate and Rating of Perceived Exertion Monark versus Fitron

| Subject | Work Rate (kpm/min) | Rating of Perceived Exertion Monark | Rating of Perceived Exertion Fitron |
|---|---|---|---|
| 01 | 720 | 12 | 10 |
| 02 | 720 | 13 | 12 |
| 03 | 720 | 14 | 12 |
| 04 | 900 | 12 | 11 |
| 05 | 400 | 13 | 12 |
| 06 | 500 | 13 | 12 |
| 07 | 500 | 14 | 12 |
| 08 | 600 | 13 | 13 |
| 09 | 900 | 13 | 12 |
| 10 | 900 | 13 | 13 |
| 11 | 1100 | 12 | 12 |
| 12 | 700 | 12 | 13 |
| 13 | 600 | 15 | 10 |
| 14 | 600 | 10 | 10 |
| 15 | 1100 | 15 | 13 |
| 16 | 1000 | 13 | 13 |
| 17 | 600 | 12 | 13 |
| Mean | 738.82 | 12.94 | 11.88 |
| SD | 211.48 | 1.23 | 1.09 |

## Appendix J

Electromyographic Activity of Four Right Leg Muscles
During Isotonic (Monark) Bicycle Ergometer Exercise

| | Vastus Lateralis | | Biceps Femoris | | Tibialis Anterior | | Gastrocnemius | |
|---|---|---|---|---|---|---|---|---|
| Subject | Start | Finish | Start | Finish | Start | Finish | Start | Finish |
| 01 | 156.5 | 324.0 | 160.2 | 91.0 | 105.6 | 171.1 | 244.0 | 102.0 |
| 02 | 165.2 | 319.3 | 161.5 | 106.4 | 29.4 | 231.2 | 238.6 | 66.1 |
| 03 | 138.3 | 291.2 | 149.2 | 101.9 | 132.1 | 154.1 | 189.3 | 65.5 |
| 04 | 133.6 | 282.0 | 152.1 | 345.0 | 55.7 | 174.4 | 231.4 | 14.2 |
| 05 | 152.1 | 300.5 | 148.4 | 77.9 | 300.5 | 200.3 | 267.1 | 74.2 |
| 06 | 143.1 | 308.3 | 176.2 | 55.1 | 18.4 | 190.8 | 242.2 | 29.4 |
| 07 | 133.5 | 306.2 | 151.3 | 85.4 | 49.8 | 113.9 | 199.4 | 71.2 |
| 08 | 136.5 | 267.5 | 142.0 | 100.1 | 32.8 | 169.3 | 214.8 | 80.1 |
| 09 | 116.3 | 307.5 | 131.3 | 20.6 | 49.3 | 170.6 | 318.8 | 26.3 |
| 10 | 126.0 | 313.2 | 140.4 | 334.8 | 324.0 | 151.2 | 165.6 | 99.0 |
| 11 | 144.8 | 304.1 | 141.2 | 92.3 | 85.1 | 206.3 | 206.3 | 81.5 |
| 12 | 134.0 | 289.9 | 143.1 | 47.7 | 89.9 | 214.7 | 216.5 | 99.1 |
| 13 | 134.0 | 306.5 | 152.4 | 67.0 | 43.6 | 224.5 | 259.6 | 40.2 |
| 14 | 132.8 | 298.9 | 147.6 | 317.3 | 5.5 | 166.1 | 265.7 | 310.0 |
| 15 | 125.5 | 295.2 | 129.2 | 332.1 | 324.0 | 199.4 | 228.8 | 70.1 |
| 16 | 137.3 | 304.2 | 148.4 | 98.3 | 139.1 | 157.7 | 241.2 | 92.8 |
| 17 | 157.8 | 289.9 | 154.1 | 113.8 | 73.4 | 139.5 | 341.3 | 106.9 |
| Mean | 139.3 | 300.5 | 148.7 | 55.7 | 45.8 | 178.5 | 239.5 | 62.9 |
| SD | 12.7 | 13.8 | 11.2 | 53.3 | 56.7 | 31.5 | 43.7 | 40.3 |

Numbers represent degrees out of a 360-degree circle
"0" degrees represents the straight-down position for the right pedal and crank

## Appendix K

Electromyographic Activity of Four Right Leg Muscles During Isokinetic (Fitron) Bicycle Ergometer Exercise

| | Vastus Lateralis | | Biceps Femoris | | Tibialis Anterior | | Gastrocnemius | |
|---|---|---|---|---|---|---|---|---|
| Subject | Start | Finish | Start | Finish | Start | Finish | Start | Finish |
| 01 | 122.4 | 262.8 | 133.2 | 75.6 | 338.4 | 140.4 | 259.2 | 36.0 |
| 02 | 153.7 | 285.5 | 150.1 | 91.5 | 32.9 | 168.4 | 172.0 | 47.6 |
| 03 | 112.8 | 283.9 | 138.3 | 109.2 | 119.9 | 158.6 | 182.0 | 72.8 |
| 04 | 141.0 | 285.7 | 141.0 | 14.8 | 59.4 | 155.8 | 232.5 | 354.4 |
| 05 | 128.3 | 291.1 | 137.7 | 269.2 | 350.6 | 134.6 | 347.4 | 73.6 |
| 06 | 122.3 | 290.1 | 223.7 | 28.0 | 29.7 | 167.8 | 216.7 | 38.5 |
| 07 | 138.6 | 297.0 | 141.9 | 72.6 | 42.9 | 138.6 | 214.5 | 66.0 |
| 08 | 125.3 | 278.4 | 132.2 | 278.4 | 3.5 | 250.6 | 187.9 | 69.6 |
| 09 | 129.9 | 300.5 | 133.6 | 13.0 | 53.8 | 152.1 | 319.1 | 13.0 |
| 10 | 117.4 | 304.6 | 132.1 | 304.6 | 308.3 | 150.5 | 156.0 | 73.4 |
| 11 | 123.2 | 291.8 | 128.9 | 47.4 | 22.7 | 170.6 | 193.3 | 45.5 |
| 12 | 113.8 | 278.9 | 126.6 | 49.6 | 91.8 | 161.5 | 179.8 | 113.8 |
| 13 | 139.8 | 290.1 | 153.8 | 28.0 | 31.5 | 157.3 | 277.9 | 349.5 |
| 14 | 139.4 | 296.5 | 148.3 | 296.5 | 111.2 | 165.9 | 188.9 | 300.1 |
| 15 | 116.1 | 270.9 | 127.7 | 34.8 | 336.7 | 143.2 | 209.0 | 309.6 |
| 16 | 129.9 | 289.4 | 155.8 | 118.7 | 55.7 | 141.0 | 270.8 | 66.8 |
| 17 | 138.8 | 270.6 | 311.5 | 249.2 | 49.8 | 138.8 | 238.5 | 40.9 |
| Mean | 129.0 | 286.3 | 153.9 | 37.7 | 35.2 | 158.6 | 226.2 | 37.1 |
| SD | 11.5 | 11.2 | 46.4 | 84.1 | 46.9 | 26.5 | 53.4 | 46.5 |

Numbers represent degrees out of a 360-degree circle
"0" degrees represents the straight-down position for the right pedal and crank