RATINGS OF PERCEIVED EXERTION DURING STEADY-STATE EXERCISE USING LEG-ONLY VERSUS ARM-AND-LEG CYCLE ERGOMETRY

by

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(ABSTRACT)

Past psychophysiological research has led many investigators to believe that perceived effort during exercise is lower with greater active muscle mass (Hagan, et al., 1983; Sargeant & Davies, 1973; Shephard, et al., 1992; Stenberg,et al., 1967), presumably because the effort is distributed to more muscle tissue. The purpose of this investigation was to compare the Ratings of Perceived Exertion (RPE) of college-age females during steady-state leg-only (LE) and combined arm-and-leg exercise (ALE) using the 15-point Borg RPE scale. Volunteer subjects were 16 healthy, physically active female students, mean age 21.0 years (SE 0.33) and a percent body fat of 22.1 (SE 1.1). Each subject completed a graded maximal exercise test on a Monark 880 LE cycle ergometer. Exercise intensity during two subsequent 30-minute exercise treatments was then maintained at the HR corresponding to 70% of the subject's tested functional capacity (VO_2max). The exercise treatments were two randomized bouts separated by at least 48 hours but not more than one week, one each using a Monark 880 cycle ergometer (LE) and a Schwinn Air-Dyne (ALE). Mean RPEs were 13.7 (SE 0.2) for the LE session, and 13.0 (SE 0.3) for the ALE session. Mean heart rates were 172.8 bpm (SE 1.18) for the LE session, and 170.6 bpm (SE 1.26) for the ALE session. Mean VO_2s were 30.7 ml/kg/min (SE 0.76) for LE and 30.1 ml/kg/min (SE 0.68) for ALE. Workload

means were 120.0 Watts (SE 3.83) for LE and 127.7 Watts (SE 4.11) for ALE. Repeated measures ANOVA revealed no significant differences between the two modalities for RPE ($p < 0.07$) or VO_2 ($p < 0.12$), but significant differences for HR ($p < 0.006$) and workload ($p < 0.0003$). Tukey's post-hoc test for simple effects determined that time effects were significant ($p < 0.0001$) regardless of modality, with RPE and HR measurements at minutes five and ten differing from those at minutes 15, 20, 25, and 30 ($p < 0.05$) during both LE and ALE bouts. The results of this investigation indicate that no significant perceived effort difference exists between these LE and ALE modalities over a 30-minute exercise bout at the same HR-regulated intensity.

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CHAPTER I

INTRODUCTION

Introduction

Cognitive processing has become an important construct in the arena of sports performance, as a competitor's perceptions and concentration greatly affect outcomes. Psychology and perception are also relevant to those engaged in fitness programs, especially in the realm of exercise compliance. One of the keys to enhancing compliance in the exercising population may be through a better understanding of individual perceptions of exercise stress and the associated effects on enjoyment of exercise. Borg (1970) recognized that "man reacts to the world as he perceives it, and not as it really is" and developed a subjective perception scale to accompany the objective physiological measures traditionally obtained during exercise research. The Borg Rating of Perceived Exertion (RPE) Scale evolved into a 15-point scale ranging from 6 (minimal perceived exertion) to 20 (maximal) having verbal anchors attached to odd-numbered ratings. A perceived exertion rating of 7 is described as "very, very light," with the descriptors increasing to "very, very hard" at number 19.

Development of a Psychophysical Scale

During the 1950's and 1960's, scientists and clinicians became increasingly aware of discrepancies between individuals' subjective estimates of illness and work capacity and their actual quantitative, physical indices of health and fitness. Attempting to find a relationship between such subjective and objective measures, several early investigations demonstrated a consistent, positively accelerating correlation between perceptions of force and actual pedal resistance on a cycle ergometer (Borg, 1962; Borg, 1970; Borg, 1973). However, quantifying these relationships became mathematically complex, and Borg (1973) noted that a simpler method of relating perceptions to physical indices was necessary for application in clinical settings. He then not only refined the relationship to allow interindividual comparison, but also developed a scale in which ratings of perceived exertion and heart rate were highly correlated (0.80 - 0.90) during varied exercise intensities. According to this scale, ranging from 6 to 20, each numerical point would correspond to approximately one-tenth the subject's heart rate, and verbal anchors would provide categories with which to more accurately gauge perceived exertion (Borg, 1973). Thus, RPE would show a linear rise with increasing HR and VO_2 caused by increasing workload.

This RPE scale, based on cycle ergometry, would be a convenient means of assessing subjective responses to the HR-VO_2 -workload relationship, and it would also allow interindividual comparison of perceived effort that previous methods did not (Borg, 1970). Previous methods, such as ratio-scaling and magnitude estimation, were described as "good enough for rough general descriptions and comparisons," (Borg & Noble, 1974) but provided no indication of actual intensity. For example, on a magnitude estimation scale of one to ten, subject A may perceive cycling at 150 Watts as a '4' and subject B, a '6'. Despite these numbers, we cannot determine if the workload is actually more difficult for B than it is for A because this numerical rating is largely relative, telling observers only the relationship of the intensity to some other subjective frame of reference, which is likely to be different for each individual. If categorical verbal descriptors are added to these ratings, however, a rating of '4' corresponding to 'light' would imply an easier perception than a rating of '6' denoted by 'heavy.' To further increase the accuracy of interindividual comparison in this manner the numerical scale is related to some physiological variable, such as HR, which is a known indicator of physical stress. Thus, the workload would be subjectively perceived by subject B as more difficult, and physically it would also be more stressing. Borg recognized the weaknesses of such methods as magnitude estimation, and utilized the above principles in developing his RPE scale.

Numerous investigations involving Borg's RPE scale have demonstrated its validity and reliability in producing linearity between RPE, HR, VO_2 , and exercise intensity (Borg, 1962; Borg & Linderholm, 1967; Burke & Collins, 1984; Skinner, et al., 1973a; Skinner, et al., 1973b; Stamford, 1976). In fact, RPE has become so widely accepted as a subjective indicator of physical effort that the American College of Sports Medicine has included its use, in conjunction with HR for exercise prescription, into their guidelines (1990).

Other similar 'psychophysical' scales have been utilized for specific purposes, or based upon investigator preference, all of which generally exhibit the same linear increase of RPE with increasing HR and VO_2 (Borg, 1973; Monahan, 1988; Robertson, 1982). However, despite the validity of these and other scales for various purposes during exercise, the 15-point 'Borg Scale' has become the standard by which findings related to perceived effort are compared. Ratings of perceived exertion are now commonly recorded as primary variables during graded exercise tests and other supervised exercise sessions. But despite widespread use of the Borg Scale as an aid in gauging exercise intensity and developing exercise prescriptions for traditional modes of exercise (treadmill, cycle ergometry), its validity for newer exercise modalities has not been thoroughly reported.

The Use of RPE in Exercise Prescription

The psychophysiological research leading to such widespread use of ratings of perceived exertion has highlighted many instances in which RPE may be a critical variable in the assessment of exercise intensity and in the prescription of exercise. Pollock and colleagues (1986) have reported that the two major deterrents to exercise program compliance are exercise of extended duration (greater than one hour) and high-intensity exercise. Their experience has been that exercise sessions of predominantly moderate intensity and lasting no longer than 60 minutes are desireable for the promotion of cardiovascular fitness and exercise adherence. If the subject feels he is working too hard, his enjoyment of, and desire to adhere to, exercise may likely be low. Similarly, a person may be reluctant to continue an exercise program which fails to produce training effects due to excessively low workloads. Therefore, a person can be trained in the use of the RPE scale as an aid in monitoring and adjusting exercise intensity. Once the subject is familiar with the rating scale and its relationship to physiological parameters, RPE ratings given during exercise show consistent and high correlations with HR, VO_2 , and minute ventilation (V_E), (Ekblom & Goldbarg, 1971; Skinner, et al., 1973a). The subject would then use RPE to regulate his or her own exercise intensity within tolerable limits while ideally remaining within the training HR prescription, an aspect which may enhance enjoyment, self-efficacy, and, ultimately, compliance to an exercise program.

The Combination of HR and RPE in Exercise Prescription

In relation to maintaining workloads, Borg (1982) stated that when used individually neither HR nor RPE is an "accurate indicator of 'dangerous strain'...they complement each other". Therefore, an exercise prescription incorporating both HR and RPE into workload determination may allow adjustments in exercise which prevent high or low extremes in intensity.

This method of exercise prescription may be superior to prescribing by HR alone for several reasons. First, by the popular ten-second pulse count method, an error in pulse count can result in a HR aberration six times the number of miscounted beats. In this instance, a cardiac patient might then adjust exercise intensity to a dangerously high level, or to a lower level, conferring fewer cardiovascular benefits. Instead, if a patient is made familiar with the subjective feelings at a given HR, and learns to regulate exercise intensity to this level, RPE can act as a safeguard along with HR to accurately gauge exercise intensity.

Additionally, ratings of perceived exertion should be utilized along with HR because RPE can be obtained without interruption of activity. In many modalities, pulse rate cannot be obtained during exercise, due often to the jarring nature of these activities or the inability to use the hands frequently during arm exercise. Since HR is known to quickly decline immediately after exercise cessation, obtained HR values may be lower than actual exercise heart rates. RPE, then, can provide a measure of exertion throughout exercise, which can be compared with HR periodically during breaks in a training session.

Exercise prescription using RPE is also promising for situations in which subjects cannot, for whatever reason, palpate their own pulse (Borg, 1962), or for those whose HR is pharmacologically or otherwise altered (Ekblom & Goldbarg, 1971; Pollock, et al., 1986). RPE has been shown in these studies to be unaffected by various medications, including parasympathetic blockers and beta-adrenergic blockers, despite changes in HR. Therefore, the normal HR-RPE relationship is skewed and exercise prescription becomes more complex, increasing the importance of monitoring subjective perceptions along with physiological measures (Ekblom & Goldbarg, 1971). If such patients are trained in relating their own perceptions to given workloads, and associating these consistently with RPE, they may be able to monitor their own exercise sessions reliably despite alterations in HR. For these reasons, incorporating RPE with heart rate in exercise prescription may diminish the potential of inappropriate exercise intensities.

An additional consideration for expanding the use of RPE in exercise prescription is the desire of many persons to 'cross-train,' or exercise using multiple modalities. Researchers have suggested that the amount of muscle mass involved in exercise plays a critical role in perceived effort. For any given workload, perceived effort should be lower with greater active muscle mass (Bergh, 1976; Stenberg, 1967), presumably because the effort is distributed to more muscle tissue. If this is true, then at the same exercise intensity, RPE should be lower for cycle ergometry than for arm ergometry since the involved leg muscles in cycling are much larger than those in the arms, a premise demonstrated by Ekblom & Goldbarg (1971). Furthermore, Mostardi, et al. (1981) demonstrated that subjects could exercise at a higher percentage of

VO_2max at a lower HR using arm-and-leg exercise (ALE) than using legs-only exercise (LE). It is therefore reasonable to assume that a person could exercise at a higher workload, producing a similar RPE, on a combined arm-and-leg ergometer than on a leg-only ergometer (Milesis, et al., 1991).

Statement of the Problem

A majority of the RPE research was conducted before the general public had begun to embrace a variety of fitness activities. Currently popular are such wide-ranging exercise modalities as in-line skating, nordic skiing, stair-stepping, and combined arm-and-leg ergometry. However, perception-related research on the performance of such activities has not been widely reported in the literature. Most of the available research focuses on responses to exercise on the treadmill or bicycle ergometer, with the intention of determining the relationships between psychologic and physiologic variables in these activities. In these studies, investigators have shown correlation coefficients between HR and RPE averaging 0.82 (Morgan, 1973), indicating that in these exercise modes, RPE is a valid indicator of physiological effort based upon heart rate.

However, the HR-RPE relationship that has been demonstrated primarily on the treadmill and cycle ergometer has not been widely demonstrated in the arm-and-leg modality, which is used extensively in cardiac rehabilitation programs, among others. Despite a lack of substantial evidence, the use of RPE in conjunction with HR for exercise prescription has become widely accepted, perhaps erroneously, for use in various modalities. Noble (1982) states that "the simplicity and practical value of the scale has led both to its wide use but also to its misuse...the rugged usefulness of the scale in one clinical setting has led to its application in others where another instrument might be more appropriate." If the HR-RPE relationship is shown to be consistent across various exercise modalities, exercise physiologists would then be able to prescribe exercise by both HR and RPE with confidence of its validity.

Therefore, the purpose of this study was to explore this issue in an understudied population by comparing the RPEs of college-age females during LE and ALE using the (15-point) Borg RPE Scale. In recognition of the widely used clinical method of prescribing exercise by HR, exercise intensity was to be maintained at the HR corresponding to 70% of the subject's functional capacity (VO_2max) based upon a graded maximal exercise test performed on a LE ergometer. Knowing from previously cited research (Borg, 1970; Borg & Linderholm, 1967; Skinner, et al., 1973a) the linearity and validity of the HR-RPE relationship during LE, the same could be assumed for ALE if Ratings of Perceived Exertion values did not differ between LE and ALE during exercise at the same HR-regulated intensity. Subjects served as their own controls, with the LE session as the control condition and the ALE session the experimental condition. Dependent variable RPE was monitored based upon the independent variables HR, mode of exercise, and time.

Research Hypothesis

In order to facilitate this investigation, the following research hypothesis was generated:

H_0: At the same HR-regulated workload, RPEs during ALE were not different than RPEs reported for LE during a 30-minute exercise session.

Statistical Indices:

Level of Significance (a) :	$p <= 0.05$
Type II Error (ß) :	0.591
Degrees of Freedom :	15
Effect Size:	0.4739

Significance of the Study

Past research, while validating the use of HR and RPE in the prescription of exercise for the treadmill and leg-only ergometer, has failed to conclusively justify the application of this method to other modalities. With the more recent popularity of a wide range of exercise modalities, it is necessary that the exercise physiologist be familiar with these modes and capable of providing the most optimal exercise program, one which is truly applicable to a variety of modalities.

Other aspects of the prescriptive use of HR and RPE remain in question. For example, research utilizing female subjects is lacking in the literature, despite indications that males and females may perceive exertion differently (Noble, et al., 1981). Additionally, most previous studies failed to incorporate exercise bouts of long duration, although this is the type of bout most commonly prescribed for fitness, weight loss, or endurance purposes.

In order to incorporate both HR and RPE into exercise prescription, the relationship between these variables must be elucidated for a variety of modalities, program types and duration, and for both genders. An important question is the generalizibility of exercise prescription to different modes of exercise than the mode on which a GXT is performed. Therefore this study will help to determine the HR-RPE relationship between leg-only and arm-and-leg ergometry using females in a long-duration exercise session.

Delimitations

The following delimitations were imposed by the investigator:

1. The subjects were 16 non-smoking, non-obese (< 30% body fat) females, aged 18-23 years, currently attending VPI & SU. Subjects were physically active, having participated in regular physical activity at least three times each week for the six months previous to this study, and were not familiar with the Borg RPE scale.
2. Modes of exercise were limited to cycle ergometry using the Monark 880 cycle ergometer and combined arm-and-leg ergometry using the Schwinn AirDyne, and the graded exercise test was performed only on the Monark 880 ergometer.
3. Exercise sessions were scheduled not less than 48 hours apart to minimize memory of previous sessions (Borg, 1982), and not greater than seven days apart to assure constancy of exercise training values.

4. Exercise sessions were to be 30 minutes in duration at a heart rate corresponding to 70% of VO_2max (as determined by graded maximal exercise test on the Monark 880 cycle ergometer; see Appendix A) following a two-minute warm-up at minimal workload.
5. The variables selected for evaluation included:
    a. Ratings of Perceived Exertion (RPE): Subjective ratings recorded during the final 15 seconds of each stage during the GXT, and every 5 minutes and during the last 15 seconds of the 30-minute exercise sessions.
    b. Heart Rate (HR)
    c. Oxygen consumption (VO_2)

Limitations

The following limitations apply to the findings of this study, whereby results can be generalized only to the following situations:

1. Subject populations comprised of females between the ages of 18 and 23 who are physically active, non-smoking, non-obese, and unfamiliar with the Borg RPE scale.
2. Exercise of 30-minutes' duration in which intensity is prescribed and maintained at heart rates equal to 70% of VO_2max, based on a graded maximal exercise test performed on a cycle ergometer.
3. Exercise using leg-only cycle ergometry and/or combined arm-and-leg ergometry using a Schwinn AirDyne or similar air-braked ergometer.

Basic Assumptions

1. Subjects were free of physical or mental disorders which would alter either physiological or perceived exertion responses.
2. Conditions external to the study, such as menstrual cycle life stressor effects, did not affect physiological or perceived exertion responses.
3. Subjects understood and followed the RPE instructions and honestly reported OVERALL, rather than LOCAL, perceptions of exertion.
4. Memory of perception from one exercise session to the next did not affect the latter session RPE ratings (i.e. no memory overlap).
5. Each subject gave maximal effort during the graded maximal exercise test for determination of functional capacity.
6. Steady-state was achieved and maintained during both exercise sessions at a heart rate equivalent to 70% of each subject's VO_2max.
7. All subjects received equal information regarding ratings of perceived exertion, and investigators gave no additional cues.
8. Subjects were unaware of the duration of exercise as it relates to RPE.
9. Subjects refrained from exercise for 48 hours and food/ beverages, other than water, for 4 hours immediately preceding each laboratory session.

Definitions and Symbols

ARM-AND-LEG EXERCISE (ALE): Exercise performed on an ergometer in which the arms and legs are utilized together against variable flywheel resistance. On most ergometers, such as the Schwinn AirDyne, the legs perform a cycling motion and the arms simultaneously move specialized handlebars in an alternating forward-and-backward motion in front of the shoulders

BORG (15 POINT) RPE SCALE: Numerical scale for the rating of subjective perceptions of exertion.which ranges in number from 6 to 20 and has verbal descriptors attached to odd-numbered ratings {see Appendix D} (Borg, 1970)

ERGOMETER: Laboratory device in which external work loads can be accurately measured and controlled for the determination of bodily responses to physiological challenge

LEG-ONLY EXERCISE (LE): Exercise performed on a cycle ergometer in which the legs perform a cycling motion against variable flywheel resistance

MAXIMAL GRADED EXERCISE TEST (GXT): Test for the measurement of maximal oxygen consumption in which the external work load is increased gradually at regular time intervals until the subject's volitional termination of the test due to excessive fatigue or discomfort

MAXIMAL OXYGEN CONSUMPTION (VO_2max, functional capacity): The maximal rate at which oxygen can be utilized by the body in aerobic metabolism (see *oxygen consumption*)

OXYGEN CONSUMPTION (VO_2): The rate at which oxygen is utilized by the body in aerobic metabolism; usually expressed as liters of oxygen per minute (L/min) or milliliters of oxygen consumed per kilogram of body weight per minute (mL/kg/min)

RATING OF PERCEIVED EXERTION (RPE): The subjective estimate of how strenuous a person feels an exercise load to be; the person 'rates' this feeling as a number on the 15-point Borg Scale (see Appendix D)

SCHWINN AIR-DYNE: Air-braked ergometer on which arm-and-leg exercise is performed, providing the added benefit of air movement - more air movement with increasing resistance

TARGET HEART RATE (THR): Exercise heart rate which the subject is to achieve and maintain during each of the two 30-minute exercise sessions, calculated during the maximal GXT as the heart rate corresponding to 70% of VO_2max

Summary

One of the keys to enhancing compliance in the exercising population may be through a better understanding of individual perceptions of exercise stress. To more thoroughly understand these individual perceptions, researchers continue to seek not only how RPE relates to other variables across exercise modalities, but also the local or central physiological origins of perceived exertion (Pandolf, 1982). More important to professionals involved in exercise prescription is the interrelationship between RPE and HR, VO_2 , and other variables which enhance the accuracy of the prescription. Another concern for these professionals is encouraging clients and patients to adhere to exercise programs, an aspect which is likely related to RPE. Pollock and colleagues (1986) reported that exercise sessions of predominantly moderate intensity and lasting no longer than 60 minutes are desireable for the enhancement of fitness and exercise program adherence, noting that "high-intensity exercise is neither enjoyable nor well tolerated by the non-athlete who is training for general health and fitness." Enjoyment, then, may well be a major factor in the perception of exertion during exercise, especially considering the more recent proliferation of various types of exercise equipment such as Nordic-skiing machines, stair-climbers, and in-line skates. The popularity of these devices may indicate that people need a variety of exercise modalities to avoid boredom and enhance enjoyment.

These and other 'unorthodox' exercise modalities have not, however, been generally utilized for professional exercise prescriptions. Treadmill exercise and cycle ergometry are the primary modes in which exercise GXT tests are performed, and research has yet to elucidate the generalizibility of exercise prescriptions from these established modes to the newer modes.

CHAPTER II

REVIEW OF LITERATURE

The use of Ratings of Perceived Exertion (RPE) has become widely accepted in the field of exercise physiology as a means of obtaining subjective appraisals of physical stress. The methods involved in exercise testing and training were perfected over many decades to determine objective, physiological responses to physical stress, however these methods did not account for the manner in which people subjectively reacted to exercise. Only during the 1950's did separate work by Stevens and Ekman (Borg & Noble, 1974) point to the need for such a subjective measurement tool. Since its introduction to American scientists in 1967-68 (Noble, 1982), the Borg RPE Scale has become the most widely accepted tool for assessing subjective perceptions during exercise, and its use during exercise testing and prescription is recommended in the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription (1991).

Development of a Psychophysical Scale

During the 1950's and 1960's, scientists and clinicians became increasingly aware of discrepancies between individuals' subjective estimates of illness and work capacity and their actual, quantitative physical indices of health and fitness. Borg (1973) described a doctor who, when testing older patients' work capacity, discovered only a 10-20% decrease in fitness in contrast to their perceptions of up to a 50% decrement. Such conflicting information between patient and doctor became a concern in efforts to accurately diagnose medical conditions and estimate functional capacities. Borg also noted additional concern regarding cases such as worker compensation, where patients could profit from falsely underestimating their work capacity so as to continue receipt of financial benefits. As a result scientists endeavored to rectify the discrepancies between perceptions and physical capacity.

Attempting to define a relationship between subjective and objective measures, several early investigations demonstrated a consistent, positively accelerating correlation between perceptions of force and actual pedal resistance during exercise of increasing intensity on a cycle ergometer (Borg, 1962; 1970; 1982; Borg & Noble, 1974). However, quantifying these relationships became mathematically complex, and Borg (1962) noted that a simpler method of relating perceptions to physical indices was necessary for application in clinical settings. He developed a scale in which ratings of perceived exertion (RPE) and heart rate (HR) were highly correlated (0.80-0.90) across varied exercise intensities, and which would also allow interindividual comparison. With this 15-point Rating of Perceived Exertion Scale, Borg proposed that each of the scale ratings, ranging from 6 to 20, corresponded to one-tenth the subject's heart rate for healthy, middle-aged males (Borg, 1970).

Establishing Validity of a Heart Rate - RPE Relationship

Many early investigators, while recognizing the potential importance of Borg's RPE Scale, sought to validate the concept before endorsing its widespread use. The HR-RPE relationship was among the first to be investigated, since Borg composed the RPE ratings scale to reflect HR responses to increasing work intensity. Borg and Linderholm (1967) examined this relationship in a group of men ranging in age from 18 to 79 years, both fit and unfit. They completed a single cycle ergometer bout in which workloads were increased by 300 kpm/min every 6 minutes until exhaustion or appearance of signs or symptoms warranting exercise termination. RPE ratings obtained between minutes 5 and 6 were shown to be linearly related to HR throughout the test for all groups of subjects. The authors also reported that for exercise at any given HR, RPE ratings increased with age.

Ekblom and Goldbarg (1971) also examined the relationship between HR and RPE. They demonstrated a high correlation between HR and RPE regardless whether subjects were exercising predominantly large (running, cycling, swimming) or small (arm cranking) muscle groups during successive, 6-minute submaximal bouts. This HR-RPE relationship was also preserved when comparing pre- and post-training responses, both HR and RPE being lower for any given submaximal work load after an 8-week training period.

In contrast to the findings of Ekblom and Goldbarg, Sargeant and Davies (1973) found that although their results indicated a linear relationship between RPE and HR, the "form of the regression relation is dependent on the type of work performed and the degree of muscle mass involvement." On a modified (arm-cranking) or standard Monark cycle ergometer, six subjects performed successive 6-minute bouts of increasing intensity until exhaustion. Exercise modes included use of one arm only, both arms, one leg only, and both legs in order to compare the prediction of oxygen consumption at an RPE of 20 (maximal) with actual $VO_{2\ peak}$ when working muscle mass is varied. The linear RPE-HR relationship was maintained for each mode, however the prediction of maximal functional capacity was not valid when active muscle mass was varied.

In a similar effort, Gamberale (1972) examined the HR-RPE relationship using successive bouts, separated by 10 minutes' rest, of a random order of exercises utilizing arms, legs, and a combination of both. The protocol assigned random successive ordering of weight-lifting (WL) and pushing a wheelbarrow (WB), followed in all trials by cycle ergometry. The results indicated that HR and RPE were linearly related, however RPE in relation to HR was greater for WL than WB, this difference purportedly related to active muscle mass. The correlation of HR and RPE was highest for cycle ergometry (0.94 versus 0.64 for WL and 0.42 for WB), perhaps due to a greater range of cycling intensities utilized and because cycle ergometry was consistently ordered (last) in the assignment of exercise modalities.

Another of the more basic tests of the Borg scale's validity and reliability was performed by Skinner, et al. (1973a). Their experiment utilized 16 subjects, half lean and half obese, to determine whether subjects could distinguish "small differences in work intensity" when exercise loads were presented in random order. Each subject completed cycle ergometry trials consisting of both a progressive trial to exhaustion and a random trial consisting of five workloads of four minutes' duration each. Results indicated that, regardless of the workload presentation order, both HR and RPE appeared to be linearly related to workload for lean and obese subjects alike. However, for any given workload, HR was slightly lower for obese than for lean subjects, as was RPE at workloads of 600, 750, and 900 kpm/min.

At lower workloads, 300 and 450 kpm/min, RPEs of obese subjects appeared to be slightly higher or equal those of lean subjects, respectively.

Utilizing the same subjects, Skinner, et al. (1973b) also compared perceptions between cycle ergometer (CE) and treadmill (TM) exercise. Each subject completed two graded exercise tests to self-reported exhaustion on each apparatus. At the same absolute VO_2 , all subjects rated CE work significantly harder than TM work and lean subjects rated the same work on both modes higher than did obese subjects. However, at the same HR, there were no significant differences in RPE when comparing TM with CE exercise or lean with obese subjects, and RPE was observed to increase rather linearly with increasing HR.

Gutmann, et al. (1981) examined the HR-RPE relationship in 20 cardiac patients at two and eight weeks post-myocardial revascularization surgery (mean number of grafts per patient = 4.2), both during graded exercise tests and regular training sessions. Training sessions, three per week, were begun two weeks post-surgery, and were part of a Phase II cardiac rehabilitation program. The resulting data suggested a "constant relationship" between HR and RPE which was present over the duration of this study. With training, the HR-RPE linearity remained, although the HRs were lower relative to any given RPE after six weeks of training, a finding also reported by Ekblom and Goldbarg (1971). In comparing RPEs for HR-matched conditions across the GXT and training sessions, RPE's were approximately the same, while workloads were higher during the GXT than during the training session - perhaps, the authors speculate, due to the longer duration of workloads during training (6 min. in GXT vs. 30-40 min. in training). These trends were maintained before and after training. The authors concluded that the linear nature of the HR-RPE relationship can contribute to increasing accuracy and safety of diagnostic testing and exercise prescription for cardiac patients. With such persons for whom maximal graded exercise testing is not prudent, the use of both RPE and HR, instead of HR alone, may provide for more effective and safe exercise testing and prescription.

These and other investigations demonstrated that the linearity of the HR-RPE relationship is consistent across a variety of conditions. It was demonstrated using modes of exercise involving arms only (Ekblom & Goldbarg, 1971; Sargeant & Davies, 1973), legs only (Borg, 1962, 1970, 1982; Skinner, et al., 1973 a&b), and arms and legs in combination, using exercise in the water (Borg & Linderholm, 1967; Ekblom & Goldbarg, 1971) and unusual modes such as wheelbarrow pushing (Borg & Linderholm, 1967). The relationship holds using both intermittent (Gamberale, 1972; Skinner, et al., 1973a) and continuous exercise, and with random and progressive presentation of workloads (Gamberale, 1972; Skinner, et al., 1973a). It has been shown to be valid in diseased (Borg & Noble, 1974; Gutmann, 1981) and healthy, with fit and unfit subjects, before and after training (Ekblom & Goldbarg, 1971; Gutmann, 1981).

<u>Local vs. Central Influences on RPE</u>

Results of these early studies led also to speculation as to the origins of physical work perceptions. Ekblom & Goldbarg (1971), for example, postulated two separate factors which contribute to the evaluation of exertion:

local and central. The local factor included "feelings of strain in the working muscles," whereas the central factor included "perceived tachycardia, tachypnea, and even dyspnea." They further proposed that the local factor was dominant in determining RPE during exercise using small muscle groups. Therefore, persons exercising large muscle groups would utilize a combination of local and central cues since the exercise places greater stress on the pulmonary and circulatory systems

Many subsequent investigations attempted to differentiate the effects of these local and central factors. To isolate various potential variables, certain aspects of these studies were kept constant while other variables were altered. For example, Cafarelli (1977) manipulated pedalling rate and resistance during submaximal cycling exercise and concluded that under the conditions of this study, peripheral input was primarily responsible for the effort sense, but that central input acted as an "amplifier that potentiates the peripheral signal in proportion to the metabolic demand for oxygen." Robertson (1982) acknowledged this potentiating effect of central factors, but proposed that consciously monitored central factors may contribute more significantly to the sensation of effort. He suggested that these variables, such as ventilatory effort and breathing discomfort, must contribute to effort sensation, since both V_E and RPE have been altered, at the same VO_2, by manipulating only ventilatory drive.

A number of reviews have been published on this topic alone (Mihevic, 1981; Pandolf, 1982), and many investigations are available to support and dispute both local and central input to the effort sense. However, very few investigators were able to define a causal relationship between any physiological indicator and perceptions of exertion. In her review of many of these studies, Mihevic concluded that the perception of exertion is, as Borg and Noble (1974) suggested, a "Gestalt," or combination of numerous physiological and psychological signals. Borg and Noble also suggested the importance of previous experiences in the integration and formation of effort perception. Furthermore, the manner in which the various cues are integrated into the "Gestalt" seems to be largely dependent upon "the mediating influence of factors such as exercise intensity, work duration, lag time of neurogenically vs. biochemically governed responses, and type of exercise as well as individual differences" (Mihevic, 1981), i.e. a combination of local and central factors. While RPE does appear to be dependent upon a variety of factors, a few variables, including HR, VO_2, and blood lactate (BLa), have been identified as perhaps the primary correlates with RPE.

Effects of Heart Rate Manipulation on RPE

Since HR and RPE had shown a consistent, linear relationship using a variety of subjects, modalities, and protocols, some further research in this area focused on manipulating HR, while maintaining other variables, to determine the RPE response.

Pandolf, et al. (1972) manipulated HR, using a heated environment, to determine whether HR was indeed a primary factor in rating perceived exertion. Ten fit subjects completed 5 constant-load cycle ergometry sessions, 30 minutes' duration each, on separate days. Subjects performed equivalent workloads (40% VO_2max) in temperatures of 24, 44, and 54 degrees C, and non-equivalent workloads at 24 degrees C. The results indicated that RPE did not follow HR when the increases in HR were stimulated by external heat, but instead appeared to follow workload when presented in increments greater than 200 kpm/min. The authors concluded that subjects were able to differentiate between thermal sensations and effort sensations.

With contrasting results, Skinner, et al. (1973b) also used conditions of excess heat to compare perceptions among lean and obese persons, as part of their previously cited study. Subjects completed a graded TM test eight times, four of these at elevated room temperature between 31 and 33 degrees C, and four at normal temperature (23-25 degrees C). Their findings indicated that RPE did follow the HR response although VO_2 remained the same. Lean subjects reported slightly higher RPE's during excess heat when compared to normal condition, whereas the obese subjects did not appear to differentiate between the two thermal conditions. In this investigation the linearity of the HR-RPE relationship was preserved despite the heat-induced HR increase.

Noble, et al. (1973) likewise utilized excess heat to determine effects on RPE. Six subjects performed 30-minute cycle ergometer trials, three at neutral temperature (24 degrees C) and one each at 44 and 54 degrees C. The neutral trials were performed at 48%, 60%, and 68% VO_2max , while both excess heat trials were maintained at a workload equivalent to that used during the first neutral trial (48% VO_2max). The HR-RPE relationship appeared to be preserved, both variables gradually increasing over the 30-minutes despite a plateau effect in most physiological variables measured. However, the authors' multiple regression analysis demonstrated that the variance in RPE was most closely associated with V_E in both conditions, followed by VO_2 and RQ in the neutral, and skin temperature and HR in the heated condition during the first 15 minutes of exercise. After 30 minutes in the neutral condition, respiratory rate was the primary variable influencing RPE, followed by V_E and rectal temperature. Skin temperature, HR, and rectal temperature were the primary influences, respectively, on RPE after 30 minutes in the heat. Therefore, while HR and RPE were both seen to increase with time and heat, RPE changes were more closely related to the respiratory and thermal variables.

Heart rate was likewise manipulated, via use of medications, in studies by Ekblom and Goldbarg (1971) and Davies and Sargeant (1979). Ekblom and Goldbarg in separate trials induced parasympathetic blockade (PSB) using atropine, and beta-adrenergic blockade (BAB) using propranolol during 6-minute bouts of both submaximal and maximal cycle ergometry. Ekblom and Goldbarg observed that these medication-induced changes in HR altered the normal, somewhat linear HR-RPE relationship. For any given submaximal VO_2, PSB caused higher heart rates, by 10, 15 and 28 beats, than the control condition, and BAB reduced HR by 13, 35, and 37 beats at workloads of 25, 50, and 75% VO_2max, respectively. At any given HR (i.e. 125 bpm), RPE was lower during PSB (RPE 8) and higher during BAB (RPE 15) than control (RPE 11). For any given VO_2 level, however, RPE changes were insignificant regardless of the induced changes in HR, and these HR changes failed to alter the relationship between RPE and blood lactate or pulmonary variables.

Davies and Sargeant (1979) found similar results in an investigation involving treadmill exercise after intravenous administration of atropine (PSB) or practolol (BAB). Four male subjects completed six bouts, three of these as 'short term' graded exercise tests, and three as one-hour steady-state bouts. Each type of exercise was performed as control condition, and once each after PSB and BAB. These authors found that the relationship between RPE and HR was shifted such that for any given HR, RPE was higher during BAB and lower during PSB than control. However, despite this skewed relationship, when RPE was related to relative work load expressed as a percentage of VO_2max, these differences between control and experimental conditions were eliminated.

During the hour-long session, subjects walked continuously at the speed and grade which most closely matched those at 60% VO_2max during the GXT. Data for the long session demonstrated significantly lower RPE's after 10 minutes than at the same level during GXT. When compared to the control session, RPE scores were similar among all three treatments, despite BAB-induced reductions in HR (-16 bpm) or PSB-related HR increases (+18 bpm). During the entire 60 minutes, RPE scores drifted gradually upward for both drug treatments, while the control condition produced only a minute RPE increase over time. The authors noted that this difference may have been due to greater changes in rectal and skin temperature and blood lactate with the drug treatments than with the control. These data, in agreement with the previous investigation, point to the complexities of effort sensations. These authors suggest that HR, in itself, does not appear to be a primary cue for RPE, nor does it seem to affect the RPE-relative workload relationship during short term exercise. They note, however, that further investigation is needed to elucidate the differences in perception when comparing progressive work and steady-state work at the same relative intensity.

<u>The Influence of VO_2 on RPE</u>

The relationship between RPE and VO_2 has likewise been extensively examined, both in determining the influence of VO_2 input to the perception of effort, and in using RPE to predict maximal VO_2. Ekblom and Goldbarg (1971) reported "somewhat linear" results for VO_2 in relation to RPE in both running and swimming exercise. They also found, as with HR, that for any given submaximal VO_2, RPE was greater for arm-only exercise and cycling than for leg-only exercise and running (and swimming), respectively. However, the latter modes of exercise produced higher maximal VO_2, therefore when relating RPE to <u>relative</u> VO_2 (%VO_2max), such intermodal differences disappear. This premise also held true before and after an eight-week training period.

Similar results were reported by Gamberale (1972). This author reported that RPE, when related to absolute VO_2 (l/min), was highest in weight lifting and lowest in pushing the wheelbarrow. These were also the modes in which blood lactate concentration (BLa) was highest and lowest, respectively, when related to VO_2. Relative VO_2 values were not discussed in this presentation, except where noting the logarithmic relationship between BLa and VO_2. Both studies acknowledged the rise in RPE with increasing VO_2 regardless of exercise modality.

Sargeant and Davies (1973), as part of a previously cited study, utilized reduced muscle mass exercise (single and double limb,arm- and leg-ergometry) to determine the RPE-VO_2 relationship in the prediction of maximal oxygen consumption. Their data suggested that at an RPE of 20 (maximal), RPE is more dependent upon relative VO_2 than a constant, linear

RPE-HR relationship, regardless of the muscle mass involved. Furthermore, the otherwise linear RPE-HR relationship, in the prediction of maximal functional capacity, was not maintained when active muscle mass was varied. However, the prediction of VO_2max varied little among different modes when 'net'VO_2 was utilized (i.e. VO_2 during exercise minus VO_2 pedalling at zero load) to standardize for VO_2max. Using net VO_2, the correlation between predicted VO_2max at an RPE 20 and actual observed VO_2max was quite high (r = +0.94), although the data were obtained from 26 trials using only six somewhat homogeneous subjects. Without utilizing net VO_2, the correlation coefficient for VO_2 and RPE ranged from 0.76 for one-arm to 0.88 for one-leg exercise, and 0.87 for two-leg exercise.

Other investigators have supported the prediction of maximal aerobic power using RPE. Noble, et al. (1981) found RPE a more reliable predictor of VO_2max (+2% error) than HR (-14% error) during graded treadmill exercise using 43 college-age males and females. Morgan and Borg (1976) claimed that neither RPE or HR used alone was superior to the other in predicting VO_2max at an RPE of 20 despite producing errors of 1% and 15%, respectively. However when used in combination the predictive power of HR plus RPE was significantly improved, with $R^2 = 0.73$, compared to 0.62 for HR alone and 0.65 for RPE alone.

The Relationship Between Blood Lactate and RPE

One means by which investigators have measured peripheral input to the perception of exertion has been the concentration of blood lactate (BLa), a variable which, like RPE, increases in a positively accelerating manner with exercise intensity (Borg, 1962). It is well established that the accumulation of lactic acid facilitates local fatigue during anaerobic metabolism (McArdle, Katch, & Katch, 1986). This lactate accumulation is typically accompanied by local muscular discomfort which may be consciously monitored (Mihevic, 1981), though the exact manner in which lactate is related to RPE has not been elucidated.

The data of Gamberale (1972) indicated that while RPE was closely related to both HR and VO_2, it was also closely related to BLa. The exercises (weight lifting and pushing a wheelbarrow) which produced the highest and lowest RPE values for any given VO_2 level were also those which produced the highest and lowest concentrations of BLa, respectively. This relationship led to the hypothesis that "the higher the blood lactate concentration an exercise produces compared to oxygen uptake, the higher will be the level of the overall perception of exertion as compared to heart rate," inferring that in some way BLa is directly related to RPE.

Similar data were obtained by Ekblom and Goldbarg (1971) in comparing arm and leg ergometer work. At any given maximal VO_2 or submaximal relative VO_2, RPE in arm work was significantly higher than in leg work, however when related to BLa, RPE was the same for both arm and leg exercise. When comparing cycling with running, any given submaximal absolute VO_2 saw higher RPE's for cycling, a difference which disappeared when using relative VO_2, since maximal VO_2 was lower for cycling than for running. RPE levels were the same for both modalities when related to BLa. These investigators also found that after an eight-week training program, RPE remained unchanged when related to BLa.

Ljunggren, et al. (1987) likewise found a somewhat linear relationship between RPE and BLa. Although using a different rating scale (Category-Ratio 10), they found BLa, RPE, and ratings of local aches and pains to increase similarly over time during a 15-minute bout of cycling at the workload which triggered the onset of BLa accumulation, as determined previously. In contrast, HR failed to increase over time, instead maintaining a "steady-state" level. The authors suggested that the ratings of aches and pains and overall perceptions were indicators of the "degree of anaerobic metabolism measured as blood lactate."

Effects of Workload Presentation on RPE

In addition to ascertaining the relationships among RPE and physiological variables, investigators have also taken testing protocols into consideration. Of importance are not only the types of modalities employed, but also the manner in which workloads are presented. Several investigations have focused on the influence on RPE of varying exercise protocols, such as random versus progressive workload presentation, continuous versus intermittent exercise bouts, and slower versus faster pedalling frequencies on the cycle ergometer.

Skinner, et al. (1973a), in their study comparing exercise responses between lean and obese subjects, proposed that the normal, progressive presentation of workloads in the use of the RPE scale might cause subjects to base a current rating on information from prior workloads in the trial. The data demonstrated "no significant differences in the physiological or perceptual variables studied" when comparing the random with the progressive test. They also determined that subjects could indeed differentiate small differences (150 kpm/min) in intensity regardless of the manner in which the workloads were presented.

Pairing bouts of intermittent and continuous cycle ergometer exercise, Edwards, et al. (1972) utilized four workloads of equal average power output to compare RPEs of three healthy male subjects. Each session, at workloads of 250, 500, 800, or 1000 kpm/min, was performed at 60 pedal RPM for a total work performance of 6000 kpm. Intermittent exercise consisted of 10, 30, 120, and 30-second bouts, respectively, alternating with 30 seconds of loadless pedalling. Data demonstrated RPE ratings significantly greater during intermittent than during continuous exercise at the same average power output.

Results contrary to these were reported by Stamford and Noble (1974) in a study which compared not only continuous and intermittent exercise, but also perceptual differences of various pedalling frequencies. Ten highly fit males performed paired cycle ergometry sessions (continuous and intermittent) at 960 kpm/min constant power output at pedalling frequencies of 40, 60, and 80 RPM. The sessions consisted of 15 minutes' total work time, either continuously or as three-minute bouts separated by three minutes' rest. For all pedalling frequencies, continuous exercise resulted in significantly greater RPE levels and metabolic cost (as determined by VO_2, V_E, BLa, oxygen debt, and HR variables) than intermittent exercise. The contradictory results in these two investigations may, however, reflect the large difference in rest duration during the intermittent bouts. In the previous study the rest period was 30 seconds, in comparison with three minutes in the latter which may have provided for greater lactate removal and regeneration of the CP-ATP energy system (McArdle, Katch, & Katch, 1986).

In comparing the three pedalling frequencies, Stamford and Noble reported that for both intermittent and continuous bouts, RPE was significantly lower for 60 RPM than for 40 or 80 RPM, exhibiting a parabolic relationship between RPE and pedalling rate. The 80 RPM frequency was rated as somewhat easier than 40 RPM, and both of these intermittent frequencies were rated similar to the continuous bout at 60 RPM despite the elevated metabolic cost of the continuous work. Unlike RPE, the metabolic variables in this study remained relatively constant across the three pedalling frequencies for both continuous and intermittent protocols, therefore these authors inferred that RPE does not necessarily covary with the metabolic variables.

The parabolic relationship between RPE and pedalling rate is also supported by two separate investigations by Lollgen, et al. (1975; 1980). Utilizing cycle ergometry at rates of 40, 60, 80, and 100 RPM, both studies found lowest exertion perceptions from 60-100 RPM, dependent upon the workload, regardless whether workloads were presented randomly (1975) or in successive order (1980). In the earlier study, the authors reported increased variability of RPE values with increasing pedal rates, and surmised that such high speed limb movement may somehow disturb perceptions of effort.

Cafarelli (1977), despite using the method of magnitude estimation for the perception of effort, also found that lower pedalling speeds (30 RPM) are rated as significantly more effortful than more rapid rates (60 RPM). For seven male and three female subjects this held true for each of four workloads, requiring 35, 50, 65, and 80% of VO_2max. The author noted this was the first investigation to report increasingly large differences in ratings between the 30 and 60 RPM rates as the workload was increased.

Other unique examinations of the effects on RPE of protocol manipulation were presented by Henriksson, et al. (1972) and Stamford (1976). The former investigation compared ratings of perceived exertion between eccentric and concentric muscle work on a specially designed cycle ergometer. This study supported previous findings that cycling at lower frequencies was more effortful than faster rates, and also demonstrated that at the same intensity, RPE was lower for eccentric than for concentric work. However, when compared at the same metabolic cost, eccentric work was perceived as more difficult.

Stamford compared RPE values of fourteen females when the ratings were obtained at the end of each minute of exercise (Interval), and when they were obtained during the final seconds of the entire exercise bout (Terminal). Workloads were presented in progressive and oscillating fashion, or as single, submaximal loads using treadmill walking/jogging, cycling, or stool-stepping. Data indicated that terminal ratings resulted in greater reliability (r=0.90) than interval ratings (r=0.76) for cycle ergometer work, however for all modalities studied the two rating types were highly correlated. The results of this investigation exhibited "that ratings elicited following progressive, oscillating, or single load work intensities are valid with respect to effort experienced at the time of response and are not influenced by prior ratings."

The Relationship Between RPE and Gender

In addition to the literature elucidating the complexities of effort perception, some more recent studies have recognized the importance of comparing such responses between the genders, and of examining the specific responses in females. Stamford's (1976) was one of the few investigations utilizing only female subjects. A large majority of the research had been focused on male subjects. However with an increasingly active female population these researchers sought to determine physiological and perceptual responses of women during exercise. Sidney and Shepherd, widely recognized as pioneers in the investigation of female responses to exercise, found in a 1977 study that when exercise intensity is expressed as a relative percentage of maximal aerobic capacity, RPE ratings do not differ significantly among young or old, males or females.

Noble, et al. (1981) compared male and female effort sensations in both relative and absolute terms during walking and running exercise. Twenty-one females and twenty-two males, all healthy college-age students, completed a single treadmill GXT to exhaustion, females beginning the test at 3.2 km/hour, males at 4.8 km/hour. At all absolute VO_2 levels used for comparison (0.75, 1.25, and 1.75 l/min), females rated the effort significantly higher, on average by two or more Borg scale rating points, than did males. However, when compared in terms of relative VO_2, expressed as 25, 50, 75, and 100% of each individual's VO_2max, female and male RPE's were not significantly different. The authors speculated that the absolute differences between genders may be due in part to differences in body size and cardiac output.

Many would believe that gender differences in performance are due primarily to hormonal differences. Shangold (1984) notes, however, that hormonal responses to exercise between men and women are largely similar, and that the major factor is differences 'in fitness or other factors.' Shangold also indicates that plasma hormone levels fluctuate too quickly and with a variety of causes, thereby preventing elucidation of their role in exercise performance studies. A few investigations have attempted to relate women's RPE scores to timing of the menstrual cycle, but with conflicting results (Eston & Burke, 1984; Higgs & Robertson, 1981), perhaps due to the inability to exactly pinpoint the timing or fluctuations of the many hormones responsible for the menstrual cycle. These and other investigations have contributed in recent years to the greater numbers of investigations addressing the various responses of women to physical stress. However, a significant lack of reliable information is evident regarding women's perceptions during exercise.

RPE in the Prescription and Regulation of Exercise Intensity

Once the validity and reliability of RPE had become more widely accepted, its use in exercise prescription gained favor, partially due to the ease with which it could be implemented. Its use did not require either interruption of exercise sessions or pulse palpation skills. Several groups investigated the accuracy of using RPE to regulate the intensity of steady-state exercise sessions.

Smutok, et al. (1980) utilized three treadmill walking or running trials (5 minutes' duration) for each of five different speeds (3, 4, 6, 7, & 8 mph).

The three trials comprised the estimation, production, and reproducibility phases of the study. Their results indicated that subjects could accurately reproduce the treadmill speed at which a given RPE occurred, and other variables HR, VO_2, and V_E were significantly correlated with RPE both during estimation and production trials ($r > 0.80$). However, at the same RPE the HR values were higher during both production trials than those obtained during the estimation trials. Furthermore, these differences in heart rate were accentuated when the workloads were below 80% VO_2max or RPE of approximately 12. The authors concluded that use of RPE to regulate exercise intensity is inaccurate, and potentially dangerous for cardiac populations when HR is the only physiological measure of intensity. The methodology utilized in this study has since been questioned as suspect. Noble (1982) noted that the two processes, estimation and production, entail different "psychophysical functions...most likely, the psychophysical process of reproducing an effort intensity from memory is not identical to the process of estimating effort intensity as exercise is ongoing."

This phenomenon was addressed by Dunbar, et al. (1992) in an experiment comparing estimation and production of RPE during cycle ergometry (CE) and treadmill (TM) exercise. Seventeen male subjects performed two estimation trials for each mode, during which RPE ratings at 50% and 70% VO_2max were determined. Two subsequent production trials were performed on each mode, with subjects attempting to reproduce the workloads based upon given RPE's from the estimation trials - one trial each based on TM and CE RPE estimations. The results indicated that exercise intensities using target RPEs based upon cycle ergometry GXT estimation can be accurately reproduced intra- and intermodally at 50% and 70% VO_2max. However, when treadmill GXTs were the mode of estimation, exercise intensities could be accurately reproduced only on the CE, not TM. The authors attributed differences between this study and that of Smutok et al. (1980) to the neuro-sensory cues involved in the different methods of production: this study required subjects to reproduce a certain RPE, whereas subjects in the Smutok study attempted to reproduce speeds at which certain RPE's occurred.

Glass, et al. (1992) performed a similar experiment using level treadmill running only. Subjects completed one GXT for determination of RPE responses and VO_2peak, after which a target RPE was calculated as the rating which had occurred at 75% HRpeak (using Karvonen formula). During the single production trial (EXT), subjects warmed-up for 5 minutes, then exercised for 10 additional minutes during which they could adjust TM speed whenever needed, "until they felt they were at their prescribed target RPE. The subjects controlled TM speed by prearranged hand signals, but at no time did they have any knowledge of the actual TM speed." Findings indicated significant mean differences in HR, but not for VO_2 or V_E, between the GXT and EXT sessions. However, for the last four minutes of the EXT the mean HR's were within 4 beats/minute. Thus the authors concluded that a single RPE rating derived from a GXT is an accurate means of reproducing a prescribed exercise intensity on a level TM, especially since exercise is most often prescribed within a given range rather than as one specific value.

Attempts at reproducing workloads, as in the previous studies, may be enhanced with feedback regarding one's accuracy. This concept was the basis of a walk/jog production study by Dishman, et al. (1987). Twenty-four young adult males submitted to a TM GXT, with feedback given during the test according to the treatment group to which each subject was assigned. Some (HRgroup) subjects were told when their HR was 10 and 5 bpm below, equal to, and 5 and 10 bpm greater than a previously derived target HR. (Stages of the GXT were designed to produce HR increments of 5 beats/stage, thus feedback was given only once per stage.) Other subjects (HR+RPEgroup) were given the same HR feedback, and also were encouraged to internalize feelings of exertional intensity when they reported RPE five seconds after the HR feedback. A third group (CONTgroup) received no feedback. Three subsequent walk/jog sessions were performed (on a 400-m track) in which all subjects were given a target HR value to achieve by the end of 800 meters. The HR and HR+RPE groups received appropriate feedback at the beginning and end of each session (HR+RPEgroup had constant access to the Borg scale during the trials), whereas the CONTgroup received HR feedback only at the end of the sessions. Results indicated that while such learning strategies were effective in reducing error during the first trial, the effect is diminished across trials so HR and HR+RPEgroups' error was not significantly lower than CONTgroup error by the third trial. However, significant within-group error variability prevented inter-group comparison across the three trials.

Chow and Wilmore (1984) also utilized learning strategies in comparing exercise prescription by HR-alone and RPE-alone, contrasted with a group receiving no prescription (NoRx). All subjects performed two TM GXT's to volitional fatigue, during which HR and RPE responses were recorded. The HR group received a target HR range (Karvonen method) corresponding to 60-70% VO_2max and were instructed on pulse palpation. All groups participated in six subsequent submaximal TM sessions. During the first two sessions investigators manipulated TM speed for the HR and RPE groups to provide workloads which would elicit the target intensity range. When the RPE subjects were within the appropriate HR range, the investigator told them they were within their target intensity range, and encouraged each subject to internalize perceptions at this level, as they would later exercise 'on their own' at this target intensity level. During the four subsequent production trials, both HR and RPE groups were instructed to maintain their target HR or RPE level for 15 minutes, during which they could manipulate TM speed whenever necessary to maintain the desired intensity. The NoRx group performed six identical 15-minute sessions during which they were to exercise at an intensity level which they would choose if on their own and wanting to "get in shape."

Despite using target intensity ranges rather than single values, the HR and RPE groups maintained exercise intensity at target levels with only 55.3% and 48.5% accuracy, respectively, compared to 24.5% accuracy for the control (NoRx) group. In addition, the RPE group maintained a lower mean HR than either of the other groups, indicating this method may be safer for populations in which exceeding target HR may be dangerous, i.e. cardiac rehabilitation patients. The authors were surprised by the low accuracy rate for the HR group since this method of exercise prescription is the most widely accepted, however they noted that these results were achieved with a somewhat homogeneous subject population group: young, healthy males.

They further encouraged further study among other populations and use of the combined HR-RPE exercise prescription.

RPE During Combined Arm-and-Leg Exercise

In order to facilitate the successful prescription of exercise, fitness professionals have necessarily incorporated the latest exercise modalities into programming. With greater numbers of the general public embracing exercise as a leisure-time activity, many different modes of activity have become popular, including activities such as stair-stepping, in-line skating, and various types of combined arm-and-leg exercise. In particular, combined arm-and-leg exercise (ALE) has gained widespread popularity with the advent of such stationary exercise cycles as the Schwinn Air-Dyne air-braked ergometer. As these types of modes are increasingly incorporated into exercise programming, it becomes necessary to further investigate physiological and perceptual responses during these activities. Most of the available literature focuses on the physiological responses to ALE, however some of the more recent studies investigated perceptual responses as well.

The earliest research dealing with ALE focused largely on differences in maximal oxygen uptake and its limiting factors during exercise involving different muscle groups. Astrand and Saltin (1961) found that VO_2max remained unchanged when arm exercise (AE) was added to leg exercise (LE) on a modified cycle ergometer. In 1974, Secher, et al. challenged their findings by speculating that perhaps a higher VO_2max was possible when using trained subjects for arm exercise. Thirteen elite athletes, whose sports involved considerable arm training, and three students completed maximal graded exercise tests using arms, legs, and combined arms-and-legs. The results indicated that ALE elicited a VO_2max corresponding to 106% of that during LE (AE evoked only 85% of the leg VO_2max). The investigators noted that the arms performed, on average, 27% of the work during ALE, and that this may be partially responsible for increases in work output (18%) and VO_2max due to the more efficient nature of the external work performed, as compared to the internal stabilization work the arms perform on the handlebars during maximal LE.

Bergh, et al. (1976) took this notion a step further in quantifying the specific amount of work the arms performed in ALE. While previous studies had used, but not differentiated, arm contributions ranging from 20-35% of total workload, the ten subjects in this study performed maximal exercise in which the arms contributed 10, 20, 30, and 40% of the total ALE workload. Subjects also performed maximal exercise (2-4 bouts for each mode) using uphill running, arm-cranking (AE), and upright cycling (LE). Resulting data showed that maximal VO_2 levels for LE and AE were 93% and 68% those of running, respectively. ALE values for VO_2max were not significantly different than running levels, except when arm work comprised 10% and 40% of the total workload, during which VO_2max was significantly lower than running. At ALE levels of 10, 20, and 30% arm contribution, VO_2 was higher than during LE, and subjects were able to maintain exercise at any given VO_2 for a longer duration. The authors concluded that VO_2max is dependent on the exercising muscle mass, but that it does not necessarily increase proportionately with muscle mass. While peripheral factors seemed to limit maximal VO_2 during small-muscle-group exercise (AE, LE), oxygen delivery seemed to be the limiting factor during large-muscle-group activity (running, ALE).

The data of Nagle, et al. (1984) support the notion that ALE results in increased VO_2max only when the arms contribute less than 30% of the total work. Ten healthy males demonstrated that, in progressive work tests, ALE exercise utilizing 10% arms and 90% legs exhibited significantly higher VO_2max, $V_E$max, HRmax, and power output than either ALE using 30% arms/ 70% legs, arms-only (AE), or legs-only (LE) exercise. ALE using 10% arms/90% legs was somewhat higher in VO_2max, HRmax, and power output than ALE using 20%/80%, but not significantly so. Four of these subjects also completed a legs-only (LE) progressive test with the ergometer configured so they could grip the handlebars as in conventional cycling, unlike the previous LE bout. This portion demonstrated that the "stabilizing effect occurring with hands gripping bars in conventional cycling contributes 10-20% to maximal power and therefore influences VO_2max." This protocol demonstrated somewhat greater, but statistically "similar" VO_2max values as compared to ALE bouts using 10-20% arm contributions.

Hagan, et al. (1983) found similar results when comparing cardio-respiratory responses to graded exercise among treadmill and AE, LE, and ALE ergometer exercise. When 15 male and 15 female subjects performed maximal graded exercise on each modality, maximal exercise values for VO_2, HR, and V_E were progressively greater for ALE compared to LE, and for LE compared to AE. As with previous investigations, these data indicate statistically similar maximal VO_2, HR, and V_E values for ALE and treadmill running exercise. This study also found, when using treadmill VO_2max as the true maximum, that the females achieved lower VO_2max with AE (76%) and LE (87%) than the males, who reached 85% and 95%, respectively, on AE and LE. Both genders achieved similar results when comparing ALE to treadmill VO_2max, females reaching 97% and males 98%.

An additional concern of these investigators was that arm exercise performed on an air-braked ergometer, with the arms engaged in a horizontal push-pull motion, likely induces different physiological responses than during traditional arm-cranking ergometry, including greater venous return and increased torso rotation, which may allow greater muscle fiber recruitment. The studies by Bergh, et al. (1976) and Secher, et al. (1974) involved arm cranking on modified Monark cycles, whereas Nagle, et al. (1984) and Hagan, et al. (1983) conducted their investigations using the Schwinn Air-Dyne air-braked ergometer. Hagan, et al. (1983) note that studies using mechanically-braked ergometers (Monark) generated greater V_E:VO_2 and HR:VO_2 ratios with AE than for LE and ALE (the latter two maintaining similar values), whereas the Air-Dyne induced no such differences among AE, LE, and ALE for any given submaximal workload. Therefore, results reported for different modalities must be inter-related with reference to such differences.

Milesis, et al. (1991), in recognition of the more recent trend to incorporate subjective responses to exercise, investigated the role of RPE in comparing the air-braked ALE ergometer with the traditional Monark (LE) cycle. Their subjects, 15 moderately active males, completed 6-minute bouts of submaximal exercise at 73.5 and 122.6 Watts each on the Monark ergometer and the Schwinn Air-Dyne, measuring cardiorespiratory and perceptual responses during the final 2 minutes of each bout. Significant differences between the two modalities were noted at both intensities, with HR and RQ (at 73.5 Watts), and HR, VO_2, VCO2, RQ, and RPE (at 122.6 Watts) all lower for the Air-Dyne than for the Monark. However, the investigators recognized that the air movement of the Air-Dyne provided a cooling effect, but more significantly the Air-Dyne bout involved greater muscle mass (arm-and-leg work) than the Monark bout (legs only).

Duey and Bassett (1990) utilized incremental exercise tests to compare LE with ALE exercise, with similar results to the previous study. Eight healthy males completed two tests, beginning at 98 Watts and increasing by 49 Watts every two minutes, on both the Monark ergometer and the Air-Dyne. Data analysis revealed significant differences in RPE for the two modalities at the 147, 196, and 245 Watt levels ($p < 0.05$), however no differences were seen for HR, VO_2, or V_E values at any workload. Therefore, at moderate workloads, RPE was significantly lower for ALE and for LE even though HR and VO_2 were not significantly different.

Summary

Many of the more recent investigations involving RPE recognize the popularity of alternative exercise modalities, including combined arm-and-leg ergometry. They address such issues as the safety of prescribing and regulating exercise by RPE and HR (Chow & Wilmore, 1984; Dishman, et al., 1987; Dunbar, et al., 1992; Glass, et al., 1992; Smutok, et al., 1980) across various modalities. Elucidation of this issue is important since HR and RPE are currently used in the prescription of exercise and advocated by the American College of Sports Medicine.

Interestingly, the American College of Sports Medicine also recommends steady-state exercise sessions of at least 20 minutes' duration (ACSM, 1991), however very few investigations have addressed such longer, constant-intensity exercise bouts. Noble (1974) utilized 30-minute bouts, and Davies and Sargeant (1979) used 60-minute bouts, but most of the cited literature utilized only shorter steady-state bouts, progressive or intermittent bouts. This lack of longer duration exercise in the literature is important in the study of perceived exertion since perceptual cues and responses may differ significantly between long and short duration bouts. Additionally, the body of exercise research needs to more accurately reflect the needs of the clinical exercising population, who increasingly engage in steady-state, long-duration exercise sessions to enhance healthful, rather than performance purposes.

To this end, another largely undeveloped aspect of RPE research is its practical usefulness in influencing exercise adherence. Pollock and others (1986) proposed that exercise of excessive intensity is one of two major deterrents to exercise compliance, yet few studies have attempted to utilize

RPE in this arena. Much of the literature involving RPE has focused on correlations with physiological parameters and comparing these parameters among modalities, but very little (Duey & Bassett, 1991) on comparing subjective impressions of exercise across modalities at the same intensity. Subjective evaluations and preferences of exercise modalities and intensities must play an important role in influencing an individual's exercise adherence, but this avenue of research has not been thoroughly investigated.

Another underutilized avenue of study has been the evaluation of perceived exertion among females. Sidney and Shepherd performed many of the earlier physiological investigations, but very few studies involving RPE have utilized female subjects. Noble, et al. (1981) found RPE evidence which supported the work of Sidney and Shepherd, concluding that gender-based differences in RPE found during absolute comparisons were eliminated when comparing relative responses. Stamford (1976) utilized only female subjects when comparing interval to terminal RPE ratings, but is the only such investigation using only females found in the perceived exertion literature through 1994, excepting those studies attempting to relate perceived exertion to the menstrual cycle (Eston & Burke, 1984; Higgs & Robertson, 1981). As the demographics of the exercising public shift to include more women, the literature is increasingly in need of information dealing with their physiological and perceptual responses to various types, and durations of exercise.

Regardless of gender, the literature does seem to support the notion that the amount of muscle mass involved in exercise plays a critical role in perceived effort. For any given workload, perceived effort should be lower with greater active muscle mass (Bergh, 1976; Sargeant & Davies, 1973; Stenberg, 1967), presumably because the effort is distributed to more muscle tissue. If this is true, then at the same exercise intensity, RPE should be lower for arm-and-leg exercise than for cycle ergometry than for arm ergometry since the involved muscle mass is larger, a premise demonstrated throughout this literature. Furthermore, Mostardi, et al. (1981) demonstrated that subjects could exercise at a higher percentage of VO_2max but a lower HR using arm-and-leg exercise (ALE) than using legs-only exercise (LE), and Milesis, et al. (1991) demonstrated that a person could exercise at a higher workload, producing a similar RPE, on a combined arm-and-leg ergometer than on a leg-only ergometer.

This principle may be important in evaluating determinants of exercise compliance in the public arena. Comparison of modalities which utilize different muscle masses, yet produce the same physiological responses due to constancy of overall intensity, may yield important information about perceived exertion. Use of modalities which may be perceived as being easier, despite similar physiological responses, has the potential for increasing an individual's compliance to exercise. In determining and prescribing use of such modalities, exercise clinicians may be able to greatly enhance the enjoyment, and subsequently the healthful benefits, of long-term exercise programs offered to the public.

CHAPTER III

JOURNAL MANUSCRIPT

RATINGS OF PERCEIVED EXERTION DURING STEADY-STATE EXERCISE USING LEG-ONLY VERSUS ARM-AND-LEG CYCLE ERGOMETRY

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(abbreviated title for running head)

Effect of Exercise Modality on Ratings of Perceived Exertion

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ABSTRACT

Past psychophysiological research has led many investigators to believe that perceived effort during exercise is lower with greater active muscle mass (Hagan, et al., 1983; Sargeant & Davies, 1973; Shephard, et al., 1992; Stenberg, et al., 1967), presumably because the effort is distributed to more muscle tissue. The purpose of this investigation was to compare the Ratings of Perceived Exertion (RPE) of college-age females during steady-state leg-only (LE) and combined arm-and-leg exercise (ALE) using the 15-point Borg RPE scale. Volunteer subjects were 16 healthy, physically active female students, mean age 21.0 years (SE 0.33) and a percent body fat of 22.1 (SE 1.1). Each subject completed a graded maximal exercise test on a Monark 880 LE cycle ergometer. Exercise intensity during two subsequent 30-minute exercise treatments was then maintained at the HR corresponding to 70% of the subject's tested functional capacity (VO_2max). The exercise treatments were two randomized bouts separated by at least 48 hours but not more than one week, one each using a Monark 880 cycle ergometer (LE) and a Schwinn Air-Dyne (ALE). Mean heart rates were 172.8 bpm (SE 1.18) for the LE session, and 170.6 bpm (SE 1.26) for the ALE session. Mean RPEs were 13.7 (SE 0.2) for the LE session, and 13.0 (SE 0.3) for the ALE session. Mean VO_2s were 30.7 ml/kg/min (SE 0.76) for LE and 30.1 ml/kg/min (SE 0.68) for ALE. Workload means were 120.0 Watts (SE 3.83) for LE and 127.7 Watts (SE 4.11) for ALE. Repeated measures ANOVA revealed no significant differences between the two modalities for RPE ($p < 0.07$) or VO_2 ($p < 0.12$), but significant differences for HR ($p < 0.006$) and workload ($p < 0.0003$). Tukey's post-hoc test for simple

effects determined that time effects were significant ($p < 0.0001$) regardless of modality, with RPE and HR measurements at minutes five and ten differing from those at minutes 15, 20, 25, and 30 ($p < 0.05$) during both LE and ALE bouts. The results of this investigation indicate that no significant perceived effort difference exists between these LE and ALE modalities over a 30-minute exercise bout at the same HR-regulated intensity.

INTRODUCTION

One of the keys to enhancing compliance in the exercising population may be through a better understanding of individual perceptions of exercise stress and the associated effects on enjoyment of exercise. A majority of exercise prescriptions now incorporate Ratings of Perceived Exertion (RPE), along with heart rate (HR), into workload determination to allow optimal adjustments in exercise which prevent high or low extremes in intensity. This method of exercise prescription may be superior to prescribing intensity by HR alone in situations where individuals cannot palpate their own pulse or for whom medications greatly aftect heart rate. Additionally, the use of RPE does not require interruption of activity, nor can it be altered in miscounting, as can the 10-second pulse count.

An additional consideration for expanding the use of RPE in exercise prescription is the desire of many persons to 'cross-train,' or exercise using multiple modalities such as combined arm-and-leg exercise or stair-stepping. Researchers have suggested that the amount of muscle mass involved in exercise plays a critical role in perceived effort. For any given workload, perceived effort should be lower with greater active muscle mass (Bergh,et al., 1976; Shephard, et al., 1992; Stenberg,et al., 1967), presumably because the effort is distributed to more muscle tissue. If this is true, then at the same exercise intensity, RPE should be lower for cycle ergometry than for arm ergometry since the involved leg muscles in cycling are much larger than those in the arms, a premise demonstrated by Ekblom and Goldbarg (1971). Furthermore, Mostardi, et al. (1981) demonstrated that subjects could exercise at a higher percentage of VO_2max at a lower HR using arm-and-leg exercise

(ALE) than using legs-only exercise (LE). It is therefore reasonable to assume that a person could exercise at a higher workload, producing a similar RPE, on a combined arm-and-leg ergometer than on a leg-only ergometer (Milesis, et al., 1991). Therefore, the purpose of this study was to explore this issue in an understudied population by comparing the RPEs of college-age females during leg-only (LE) and combined arm-and-leg exercise (ALE) using the (15-point) Borg RPE scale.

METHODS

SUBJECTS

Permission to conduct this investigation was obtained from the Human Subjects Committee of the Division of Health and Physical Education. The subjects were 16 healthy, active female volunteers, currently enrolled at the Virginia Polytechnic Institute and State University. Subject characteristics are presented in Table 1.

Each subject was informed of the nature of the study and the procedures in which she would be asked to participate, and completed a Health History Questionnaire to determine the individual safety of the experimental procedures . Subjects were required to read for understanding and sign for acceptance a generalized informed consent form pertaining to these experimental procedures. However, since the main dependent variable, RPE, is a subjective measure and prone to some bias on the subject's part, each subject read and signed a specific informed consent form relating only to a companion metabolic study into which the procedures for this study were incorporated. The intention of the investigator was that subjects believed

RPE to be a necessary, but secondary, aspect of the companion study, therefore the data for this study were collected as part of the companion study. Since the procedures involved are widely accepted procedures for exercise testing and prescription (ACSM, 1991), it was believed that subjects' participation in the companion study would not influence the Ratings of Perceived Exertion or the results of this study.

PRE-SESSION CONTROLS

This study utilized randomized assignment of exercise trials to avoid order of treatment effects. All sessions were performed at approximately the same time of day to minimize diurnal performance or metabolic variations, and were scheduled not less than 48 hours nor greater than one week apart. The time interval between the GXT and both exercise sessions was such that subjects' memory of previous RPEs and exercise intensities was minimized (Borg, 1962) while also maintaining constancy of subjects' fitness levels.

All instruments were calibrated to known measures preceding each GXT/ exercise session.

DETERMINATION OF MAXIMAL OXYGEN CONSUMPTION

On a day subsequent to the determination of percent body fat for the companion study, subjects reported to the Human Performance Laboratory to undergo a maximal graded exercise test (GXT) on a calibrated Monark 880 cycle ergometer. Each subject was weighed, then prepared for a three-lead electrocardiogram by which HR was monitored via a Lifepak portable defibrillator. The subject was fitted with nose clip and mouthpiece for the determination of respiratory variables. The mouthpiece was attached to a Hans-Rudolph one-way non-rebreathing valve, which in turn was connected to a Parkinson-Cowan dry gas meter for the measurement of inspiratory volume (V_I). On the expiratory side, fractional analysis of oxygen (F_EO_2) and carbon dioxide (F_ECO_2) was conducted using Ametek (Applied Electrochemistry, Sunnyvale, CA) S3A Oxygen and CD3A Carbon Dioxide analyzers.

A blood pressure (BP) cuff was placed on the left arm for the duration of the test. Each subject was then instructed on and familiarized with the testing procedure, and instructed on the rating of perceived exertion. Prerecorded instructions were played for each subject, and she also had a written copy with which to read along (ACSM, 1991). Resting HR and BP in the seated cycling position were recorded before the initiation of the exercise test.

After pedalling at 50 revolutions per minute (RPM) for two minutes with no added resistance to the flywheel (25watts), the initial workload for the test was set at 50 Watts. Each stage of the GXT was two minutes in duration, with the workload increasing 25 Watts per stage. Heart rate, V_I, and expired gas fractions (F_ECO_2, F_EO_2) were recorded every minute, with BP and RPE recorded during the last minute of each stage.

After BP measurement but before the end of each stage, the subject was instructed to "rate your exertion." The Borg RPE scale, in poster format, was in full view of the participants during all exercise sessions, and at this time the subject was presented with the scale and instructed to point to the appropriate number on the scale. The RPE scale was presented on large posters with adequate spacing between rating points to avoid any uncertainty as to the subject's intended rating, and the rating was repeated aloud for correction by the subject if necessary.

The exercise test was concluded when the subject reached volitional fatigue or could no longer maintain the required (50 rpm) cadence. After completion of the GXT, the respiratory variables V_I, F_ECO_2, and F_EO_2 previously obtained were processed by computer for the determination of each subject's maximal oxygen consumption (VO_2max). Criteria for consideration of this test as a maximal test conformed to American College of Sports Medicine guidelines (ACSM, 1991). Subsequently, 70% VO_2max and the corresponding HR were determined as the work intensity for the exercise treatments (Table 1). This exercise intensity was chosen due to its common use in fitness settings, where exercise prescriptions are given in the range of 60-80% of VO_2max (ACSM, 1991), the most typical training intensity for healthy adults.

EXERCISE TREATMENTS

Not less than two, nor greater than 7 days later, the subject again reported to the HPL for the first of two 30-minute exercise sessions, randomly assigned to condition sequence. The preparatory procedures were identical to those prior to the GXT. Again each subject listened to the prerecorded RPE instructions and read along before beginning exercise.

For the exercise session on the Monark ergometer, the subject again performed a 2-minute warm-up at 25 watts before the 30 minute session began. At the same 50 rpm cadence, a predetermined resistance (calculated from the GXT to be approximately the workload occurring at the HR which corresponded to 70% VO_2max) was then applied to the flywheel to begin the 30 minute period.

For the exercise session on the Schwinn arm-and-leg ergometer (Air-Dyne), the subject pedalled for approximately two minutes at a minimal effort load (0.5 on the Air-Dyne display) as a warm-up. To begin the 30 minute exercise session, the workload was increased to approximately the intensity level achieved at the HR corresponding to 70% VO_2max during the GXT. Work done by the arms and legs was not quantified separately because in practical settings, each subject modifies arm and leg output subjectively, and the aim of this investigation was to approximate the average home or health club exercise session. Each subject was, however, instructed to exercise equally the arms and legs.

During each exercise session, the workload was adjusted as needed at five-minute intervals to maintain the HR at a level corresponding to 70% VO_2max as determined for each individual from the GXT. Heart rate, V_I, and gas fractions were recorded each minute for the first five minutes of exercise, and thereafter at minutes 9, 10, 15, 19, 20, 25, 29, and 30, as necessary for the companion study. Blood pressure and RPE were recorded at five-minute intervals during the 30 minutes of exercise by the same method used during the GXT.

STATISTICAL ANALYSES

Two-way repeated measures ANOVAs were performed to determine main effects and interactions of exercise treatment (LE vs. ALE) and duration of exercise (5, 10, 15, 20, 25, and 30 minutes). Simple effects ANOVAs were performed when there was a significant ($p < 0.05$) exercise-time interaction. Multiple comparisons using Tukey's post-hoc test and paired t-tests were then performed when there were significant main effects. Paired T-tests were performed to compare VO_2s and workloads.

RESULTS

A summary of the exercise session responses is presented in Table 2. Two-way repeated measures ANOVAs revealed no significant differences between the two modalities for RPE ($p < 0.069$) or VO_2 ($p < 0.116$), but did find such a difference for HR. However, RPE did exhibit a significant difference between the two modes at minutes 5 ($p < 0.004$) and 10 ($p < 0.001$), as shown in Figure 1. Tukey's post-hoc test for simple effects determined that time effects were significant regardless of modality, with RPE and HR measurements at minutes five and ten differing from those at minutes 15, 20, 25, and 30 ($p < 0.05$) during both LE and ALE bouts. Paired T-tests revealed greater differences in RPE ($p<0.05$) between minute 5 and all other time intervals for the ALE session than for the LE session, but failed to find significance between minute 10 and other time intervals.

DISCUSSION

These results indicate that over a 30-minute steady-state exercise bout performed at the HR corresponding to 70% VO_2max, RPE does not differ significantly between leg-only (LE) and combined arm-and-leg exercise (ALE). However, the difference in RPE between the two modes does approach significance ($p < 0.069$), with the mean ALE value 0.7 rating points below LE. Such a difference, though not statistically relevant, may be meaningful in a clinical environment where it could in part determine whether a person would adhere to a prescribed exercise program.

Data from this study indicate that persons may, at a similar VO_2, be able to exercise at a slightly higher workload using ALE but perceive that workload to be somewhat easier than LE exercise. Statistical analyses did not bear this out, due likely to small sample size and low statistical power. In addition, the mean heart rates would be considered clinically similar, however the difference of 3 beats per minute was found to be statistically significant. These findings, if such differences are indeed significant among the larger population, may be helpful in the prescription of exercise for high risk populations for whom exceeding a target exercise intensity may be dangerous. If, as is most common, exercise is prescribed in terms of HR, patients using ALE may achieve slightly higher workloads than LE at the same target HR and RPE.

The current study was conducted using physically active female subjects, therefore caution must be exercised before applying these results to other populations, especially inactive persons. Previous perception research (Bergh, et al., 1976; Secher, et al., 1974) has suggested that localized fatigue in the arms may contribute to higher RPEs, in part due to lower muscle mass and increased accumulation of lactate. Thus, the current difference in RPE between LE and ALE exercise may not occur in those who are unaccustomed to regular physical activity. Indeed, inactive persons may perceive ALE to be more difficult due to arm fatigue, and perhaps also to the unaccustomed additional cardiovascular demand required for combined arm-and-leg exercise. Therefore, investigations involving inactive and higher risk populations would be necessary before generalizing these results to any exercise prescription guidelines.

Other investigations comparing specifically Airdyne and cycle ergometer exercise did find significant differences in RPE between the two modalities using absolute workloads, whereas the current study maintained intensity relative to each individual's tested maximal aerobic capacity. Milesis, et al. (1991) and Duey and Bassett (1991) both found RPE to be lower for ALE than LE, although the former study also found lower HR, VO_2, and RQ. These investigations support the notion that for any given absolute workload, RPE should be lower due to the distribution of the work over a greater muscle mass. Results of the current study support these findings through the first 10 minutes of exercise, however over the next 20 minutes of exercise, RPE responses did not differ significantly between ALE and LE modalities.

Astrand and Saltin (1961) suggested that over a long, incremental exercise bout, VO_2, and presumably HR and RPE, for ALE initially lags behind that of LE, then increases and equals the values for LE. The current data are in concurrence with that trend (Figures 1 & 2), with simple effects tests determining that both HR and RPE were significantly lower for ALE than for LE at minutes 5 and 10. However, over the subsequent 20 minutes the ALE values for RPE and HR did exhibit a trend to increase and equal those during LE. Oxygen consumption followed a similar trend, however the initial difference between ALE and LE was much smaller and not statistically significant. For use in exercise prescription, clinical application of this finding would compensate for lower training effects during the first 10 minutes of an exercise bout performed in similar manner.

Unlike many investigations using combined arm-and-leg exercise, the current study did not quantify the specific amount of work being performed by the arms and legs during ALE in recognition of the manner in which such exercise is typically performed in the clinical setting. However, several previous studies have suggested that decreases in VO_2 occur when the arms perform more than 30% of the total work (Bergh, et al., 1976; Nagle, et al., 1984; Secher, et al., 1974). This investigator believed, however, that since the subjects self-selected the amount of work the arms performed, the arm work likely did not approach 30% of the work as this workload may not be able to be maintained for the duration of the 30-minute ALE bout due to localized fatigue (Bergh, et al., 1976).

All observations noted in previous studies involved male subject populations, while the current study utilized only female subjects. Only one comparison study of male and female perceptions could be found. The results of Noble, et al., (1981) indicated that men and women perceive relative workloads equally, but when the loads are expressed as absolute quantities, women perceive the load as significantly more difficult than do men. Stamford (1976) found with female subjects that RPE is a valid and reliable measure of physical stress using various workload presentations with three different modalities. Other investigations involving RPE and females attempted to differentiate perceptual responses based upon timing of the menstrual cycle (Eston & Burke, 1984; Higgs & Robertson, 1981). However, Shangold (1984) noted that hormonal responses to exercise between men and women are largely similar, and that the major factor is differences in fitness or other factors. Notwithstanding these investigations, information regarding the perceptual responses of females during exercise remains sparse. The data from the females in the current study concur with that of studies using male subjects (Astrand & Saltin, 1961; Borg & Johansson, 1985; Pandolf, et al., 1972), however more investigations using male and female subjects are required to provide a more complete picture of the nature of psycho-physiological responses to exercise.

Due to the lack of significant differences between the LE and ALE exercise bouts found in the current study, it is therefore reasonable to assume that a HR and RPE exercise prescription for healthy, college-age females based upon the results of an LE graded maximal exercise test is valid for both modalities. However, consideration must be given for potential differences in RPE between these modes. Further research using males and females performing long duration, steady-state exercise is necessary to determine whether differences in exercising muscle mass or specific modalities indeed influence the perception of effort when all other variables remain constant.

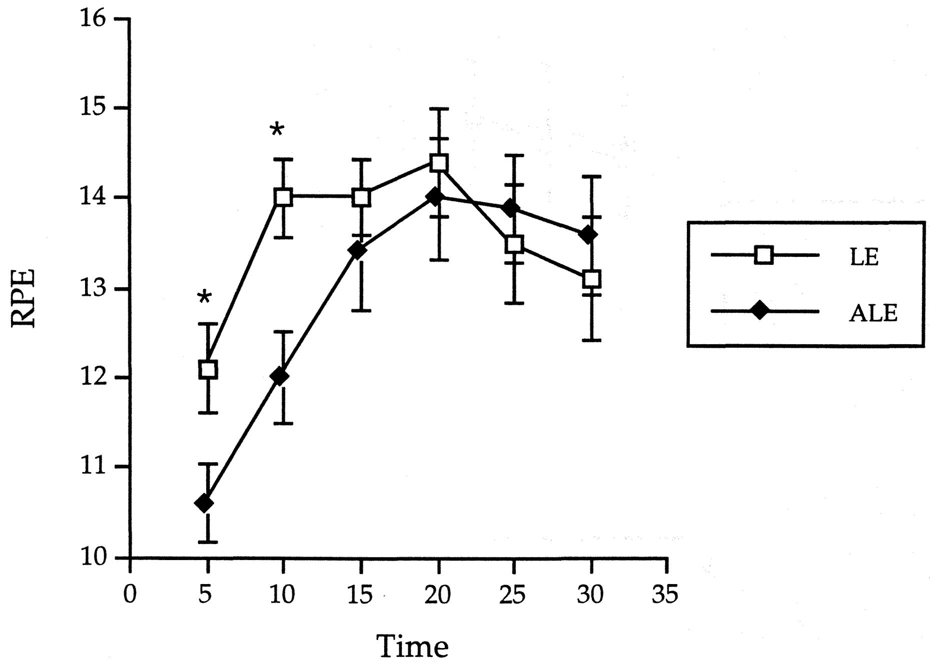
Table 1. SUMMARY OF SUBJECT CHARACTERISTICS

VARIABLE	MEAN	STD. ERROR
AGE (years)	21.0	0.33
PERCENT BODY FAT	22.1	1.1
WEIGHT (kg)	59.44	1.53
VO_2max (L/min)	2.68	0.1
VO_2max (mL/kg/min)	45.05	1.16
TARGET HR (bpm)	168.1	2.78
TARGET VO_2 (L/min)	1.88	0.07

Table 2. SUMMARY OF EXERCISE SESSIONS

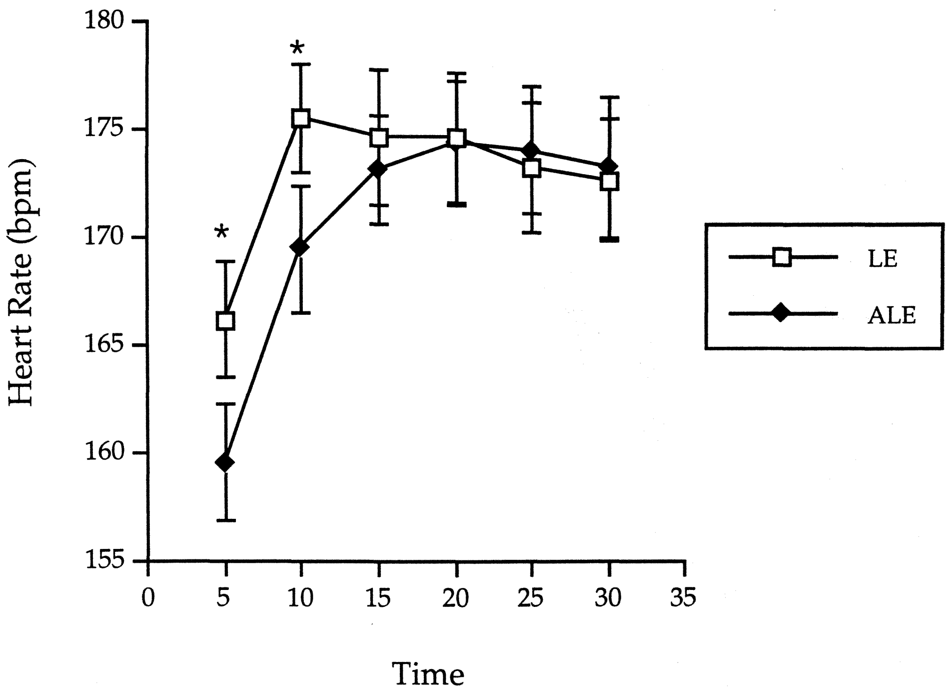
Variable	**Leg-only (LE)**	**Arm-and-Leg (ALE)**	**Significance**
RPE	13.7 ± 0.2	13.0 ± 0.3	$p < 0.069$
HR (bpm)	172.8 ± 1.2	170.6 ± 1.3	$p < 0.006^{**}$
VO_2 (L/min)	1.82 ± 0.06	1.79 ± 0.05	$p < 0.116$
WORKLOAD (Watts)	120.0 ± 3.83	127.7 ± 4.11	$p < 0.0003^{***}$

Note. Values following ± indicate SE
$^{**}p < 0.01$. $^{***}p < 0.001$



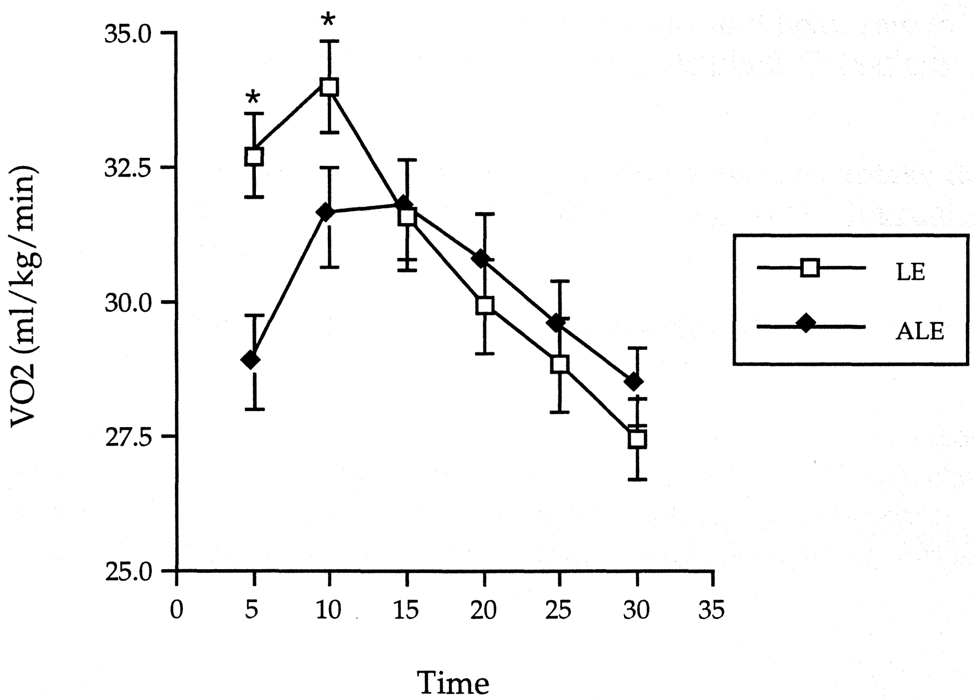
* Significant (p<0.05) difference between LE and ALE

Figure 1. Mean Rating of Perceived Exertion Across Time



* Significant (p<0.05) difference between LE and ALE

<u>Figure 2.</u> Mean Heart Rate Across Time



* Significant (p<0.05) difference between LE and ALE

Figure 3. Mean Oxygen Consumption Across Time

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CHAPTER IV

SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

Summary

The purpose of this study was to explore differences in perceived exertion across two exercise modalities, leg-only cycle ergometry (LE) and combined arm-and-leg exercise performed on the Schwinn Air-Dyne (ALE). It was the belief of the investigator that ALE, using a greater active muscle mass, would be perceived as being easier than LE despite both modalities being performed at the same HR-regulated exercise intensity. If this premise held true, it was believed that clinicians could perhaps influence adherence to exercise prescriptions by utilizing those modalities perceived as being least difficult for members of preventive or rehabilitative exercise programs. In addition, the HR-RPE relationship previously documented in other modalities would also be valid utilizing these modalities, and would justify prescribing exercise for ALE when the exercise test is performed on a cycle ergometer.

The subjects, 16 healthy, college-age females, were chosen due to the lack of literature utilizing female populations. Each subject performed a graded maximal exercise test to volitional fatigue, from which the target HR was derived as that HR corresponding to 70% VO_2max. Subjects subsequently performed two separate steady-state exercise bouts for 30 minutes at this target HR, one each using LE (Monark 880 cycle ergometer) and ALE (Air-Dyne). Since this study was designed to be more clinical in nature, workloads were not strictly subscribed to, rather the workloads were adjusted at 5-minute intervals to maintain the constant target HR for each subject, reflecting the accepted practice of prescribing intensity by target HR.

Results indicated no significant mean differences in RPE or VO_2 across the two modalities for the 30-minute sessions, although during the initial 10 minutes subjects perceived ALE to be significantly less difficult than ALE. Significant mean differences were exhibited in HR and, despite investigator attempts to maintain session heart rates at the level corresponding to 70% of each individual's maximal oxygen consumption. These data do indicate significant time effects, with RPE and HR measurements at minutes five and ten differing from those at minutes 15, 20, 25, and 30 during both LE and ALE bouts. Failure to find a significant difference in RPE between modes must be interpreted with caution, due to small sample size and low statistical power. In addition, statistical analyses performed did not take into consideration the unique parameters and size of the Borg RPE scale when computing significance.

These data suggest that the exercise treatments induced no significant effects in either RPE or VO_2 at the same HR-regulated intensity. It was believed that utilizing a greater active muscle mass would reduce local strain and feelings of effort, as had been suggested previously (Bergh, 1976; Mostardi, 1981; Stenberg, 1967) However, previous investigations made such comparisons when exercise was performed at the same absolute workload, rather than at the same relative HR-regulated intensity. In this study, oxygen consumption was similar between the two modes, indicating that physiological strain was similar as well. Despite the possibility that increasing active muscle mass may reduce local feelings of fatigue due to lesser buildup of lactate, adding arm exercise to leg exercise creates an additional cardiovascular challenge than does LE.

This study, in attempting to most closely approximate clinical exercise sessions, did not dictate the proportion of the exercise load to be performed by the arms and the legs. Subjects were encouraged throughout the ALE exercise session to exercise the arms and legs equally, but the proportions of arm and leg work were not measured. It is possible that the ALE session approximated the LE session more than desired if the subjects failed to exercise the arms adequately.

It is likewise possible that extraneous factors may have confounded the results of the current investigation. The exercise sessions were 30 minutes in duration, and though the subjects knew the duration of these bouts, all clocks were removed from the room, the subject's watch was removed, and no feedback with regard to time was provided, subjective ratings may have been affected toward the end of the session if subjects felt they were close to the end. Latzka, et al. (1989) collected, but did not use for analysis, any RPE measurements obtained during the last 5 minutes of a 30-minute steady-state exercise bout, due to the potential for such influence. In addition, perceptual ratings may have been affected by boredom or other factors which cannot be controlled for.

Research Implications

The information obtained in this study provides information regarding the psychophysiological responses of non-smoking, non-obese healthy, college-age females during prolonged steady-state exercise bouts. These were women accustomed to exercising up to 3 times per week, so may be considered physically active. Since several investigations (Noble, et al., 1981; Sidney & Shepherd, 1977) have shown that women and men perceive exercise in a similar manner when the variables being measured are considered relative to each person's maximum, one may surmise that responses of males to a similar study would be similar, however no investigations to date have demonstrated that to be true.

The results of this study also provide further justification of the validity of cross-modal exercise prescription. When a graded maximal exercise test is performed on a cycle ergometer such as the Monark 880, a similar exercise prescription may be applied both for the cycle ergometer and for the arm-and-leg modality such as the Schwinn Air-Dyne with confidence in the safety and constancy of perceptual and physiological responses in this female population.

However, further investigations involving RPE in any population need to address the differences between the estimation and production methods of obtaining perceptual information when applying exercise prescriptions. These methods have been somewhat interrelated in the literature, yet Noble (1982) noted that the two processes involve different "psychophysical functions. Most likely, the psychophysical process of reproducing an effort intensity from memory is not identical to the process of estimating effort intensity as exercise is ongoing." Therefore, these methods must be validated using various protocols and modalities.

Despite the statistically significant difference in HR between the two modalities and the lack thereof for RPE, the data provide some useful information to the clinician interested in exercise program adherence. In clinical practice, a difference in mean HR over a 30-minute exercise session of approximately 3 beats per minute is not significant when dealing with heart rates in excess of 150 bpm. Likewise, on a scale of 6 through 20, a difference in RPE of 0.6 ratings points may be clinically, if not statistically, significant. If, in an exercise program prescribed by HR, a client feels that at the 'same' HR one exercise mode is 0.6 ratings points easier on the Borg RPE scale, he/she may be more likely to continue in a program than if made to use the mode which is slightly more difficult. Pollock, et al. (1986) suggested that one of two major deterrents to exercise compliance is exercise of excessive intensity - which is a highly subjective estimation. Therefore, clients using an exercise device which is perceived to be less stressful may enjoy exercise more, and thus feel encouraged to adhere to a program of exercise over the long term.

Recommendations for Future Research

The failure of this study to find a significant difference in RPE between LE and ALE for these sessions is due in large part to low sample size. A larger sample may have parlayed a significance of $p < 0.069$ to a level less than 0.05. In addition, data analysis which takes into consideration the unique aspects and scale of the Borg RPE scale may improve the significance of such findings. Such an analysis was outside the scope of this study.

During this study, the investigator attempted to maintain HR at a constant level corresponding to that achieved at 70% VO_2max in keeping with common clinical practices. Despite a small, 2-3 beats per minute difference between these modalities, these responses were determined to be statistically significant. Although such a difference would not be clinically relevant, future studies may include protocol which adjusts work intensity more frequently than at 5 minute intervals so as to further minimize such a difference.

An additional, similarly understudied concept is the scope of perceptual responses to these two modes when workload is held constant throughout a steady-state exercise session. The current investigation found a slight difference in workloads, however they were not precisely measured. Therefore, future investigations may benefit from measuring workloads precisely if regulating intensity by HR, or by regulating exercise intensity by some relative workload. If workloads and/or RPEs are indeed found to be significantly different between modes despite similar HR and VO_2 responses, the implications for exercise prescription may be promising. Certain modalities, then, could be utilized at a somewhat higher workload than others at the same physiological intensity, and would perhaps not be perceived as being more difficult. Therefore, subjects may see greater training benefits while enjoying the training process more.

In consideration for enjoyment of exercise programs, longitudinal studies would be useful in determining whether RPE can indeed be used as a tool to improve program compliance, and in which populations it would be most useful. An additional consideration for such a study would be to minimize any potential learning effects associated with perception. This concept could not be adequately addressed in the context of only two exercise treatment sessions.

Regarding the subject population, the current study results may not be applicable to previously inactive or high risk populations, nor potentially to any group other than those tested. Perceptual responses in this study, as well as others which have used arm exercise, were likely related to localized fatigue, and therefore subject to differences in muscle mass and regular activity patterns. Since the exact mechanisms which most directly affect RPE have not been elucidated, investigators may wish to utilize various population samples with consideration of all aspects which may in part determine RPE, including both central and peripheral mechanisms.

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APPENDIX A

Methodology

Selection of Subjects

Permission to conduct this investigation was obtained from the Human Subjects Committee of the Division of Health and Physical Education. The subjects were 16 normal-weight, active females currently enrolled at the Virginia Polytechnic Institute and State University. Volunteers were recruited from several basic activity courses offered by the Division of Health and Physical Education, and from aerobic exercise classes offered by the Recreation Department.

Potential subjects completed a Health History Questionnaire to determine the safety of the experimental procedures for each subject. Each subject was informed of the nature of the study and the procedures in which she would be asked to participate. Subjects were required to read for understanding and sign for acceptance a generalized informed consent form pertaining to these experimental procedures. However, since the main dependent variable, RPE, is a subjective measure and prone to some bias on the subject's part, each subject read and signed a specific informed consent form (Appendix B) relating only to a companion metabolic study into which the procedures for this study were incorporated. The intention of the investigator was that subjects believed RPE to be a necessary, but secondary, aspect of the companion study, therefore the investigator was careful not to reveal the existence or primary purpose of this study. Since the procedures involved are widely accepted procedures for exercise testing, it was believed that subjects' participation in the companion study would not influence the Ratings of Perceived Exertion or the results of this study.

Experimental Procedures

Due to the incorporation of the companion study, and although some procedures and collected data were not required or utilized for this study, all subjects participated in all procedures for both projects. After signing the appropriate consent forms, each subject fasted for six hours before reporting to the Human Performance Laboratory (HPL), the site for all experimental procedures, for body composition measurements. Each subject submitted to skinfold measurements using the method of Jackson, Pollock, and Ward (1980). Subsequently, and in order, residual lung volume (Wilmore, et al., 1980), dry weight on land, and hydrostatic weight were determined. From these values, body density was determined, and percent body fat (%BF) estimated by the method of Siri (1961).

On a subsequent day, subjects reported to the Human Performance Laboratory to undergo a maximal graded exercise test (GXT) on a calibrated Monark 880 cycle ergometer. Each subject was first weighed, then prepared for a three-lead electrocardiogram by which heart rate was monitored via a Lifepak portable defibrillator. The subject was fitted with nose clip and mouthpiece for the determination of respiratory variables.

The mouthpiece was attached to a Hans-Rudolph one-way non-rebreathing valve, which in turn was connected to a Parkinson-Cowan dry gas meter for the measurement of inspiratory volume (V_I). On the expiratory side, fractional analysis of oxygen (F_EO_2) and carbon dioxide (F_ECO_2) was conducted using Ametek (Applied Electrochemistry, Sunnyvale, CA) S3A Oxygen and CD3A Carbon Dioxide analyzers.

A blood pressure (BP) cuff was placed on the left arm for the duration of the test. Blood pressure measurements were obtained using auscultation and a mercury sphygmomanometer. Each subject was then instructed on and familiarized with the testing procedure, and instructed on the rating of perceived exertion. Prerecorded instructions were played for each subject, and she also had a written copy with which to read along (Appendix C). Resting HR and BP in the cycling position were recorded before the initiation of the GXT.

After pedalling at 50 revolutions per minute (RPM) for two minutes with no added resistance to the flywheel, the initial workload for the test was set at 50 Watts. Each stage of the GXT was two minutes in duration, with the workload increasing 25 Watts per stage until the subject's volitional termination. Heart rate, V_I, and expired gas fractions (F_ECO_2, F_EO_2) were recorded every minute, with BP being recorded during the last minute of every stage. After BP measurement but before the end of each stage, the subject was instructed to "rate your exertion." At this time she was presented with the Borg RPE scale (Appendix D), and pointed to the appropriate number on the scale. To avoid any uncertainty as to the subject's intended rating, the RPE scale was presented on large posters with adequate spacing between rating points, and the rating was repeated aloud for correction by the subject, if necessary. In addition to the poster which was presented to subjects, the RPE Scale was in full view of the participants during all exercise sessions. After completion of the GXT, the respiratory variables V_I, F_ECO_2, and F_EO_2 previously obtained were processed by computer for the determination of each subject's maximal oxygen consumption (VO_2max).

Not less than 48 hours nor greater than one week later, the subject again reported to the HPL for the first of two 30-minute exercise sessions, presented in random order in a counterbalanced design. The time interval between the GXT and both exercise sessions was such that subjects' memory of previous RPE's and exercise intensities was minimized (Borg,1962). The preparatory procedures were identical to those prior to the GXT. Again, the subject listened to the prerecorded RPE instructions and read along before beginning exercise.

For the exercise session on the Monark ergometer, the subject again maintained a cadence of 50 RPM for approximately 2 minutes without resistance before the 30 minute session began for a 'warm-up'. At the same cadence, a predetermined resistance (calculated from the GXT to be approximately the workload occurring at the HR which corresponded to 70% VO_2max) was then applied to the flywheel to begin the 30 minute period.

For the exercise session on the Schwinn arm-and-leg ergometer (Air-Dyne), the subject pedalled for approximately 2 minutes at a minimal effort load (0.5 on the Air-Dyne display) as a 'warm-up'. To begin the 30 minute exercise session, the workload, read from the display on the ergometer, was increased to approximately that achieved at the HR which corresponded to 70% VO_2max during the GXT. This exercise intensity was chosen due to its common use in fitness settings, where exercise prescriptions are given in the range of 60-80% of VO_2max (ACSM, 1991), the "typical training intensity for healthy adults." Work done by the arms and legs was not quantified separately because in practical settings, each subject modifies arm and leg output subjectively, and the aim of this investigation was to approximate the average home or health club exercise session. Each subject was, however, instructed to exercise equally the arms and legs.

During the exercise session in each modality, the workload was adjusted to maintain a steady state based upon the HR which corresponded to 70% VO_2max. Heart rate, V_I, and gas fractions were recorded each minute for the first five minutes of exercise, and thereafter at minutes 9, 10, 15, 19, 20, 25, 29, and 30, as necessary for the companion study. Blood pressure and RPE were recorded at five-minute intervals during the 30 minutes of exercise by the same method used during the GXT.

All instruments were calibrated to known measures preceding each GXT/ exercise session. Pneumotach was calibrated to known volumes, gas analyzers to known concentrations, and cycle ergometer to known workloads.

Research Design

This study consisted of a counterbalanced design with randomized exercise trial assignment to balance any order-of-treatment effects. In addition, trials were completed no less than 48 hours apart to minimize memory effects on perceived exertion, and no more than one week apart to assure constancy of exercise training values.

Statistical Procedures

Two-way repeated measures ANOVAs were performed to determine main effects and interactions of exercise treatment (LE vs. ALE) and duration of exercise (5, 10, 15, 20, 25, and 30 minutes). Paired T-tests were performed to compare VO_2s and workloads. Simple effects ANOVAs were performed when there was a significant ($p<0.05$) exercise-time interaction. Multiple comparisons using Tukey's post-hoc test and paired t-tests were then performed when there were significant main effects.

APPENDIX B

Informed Consent Form

LABORATORY FOR EXERCISE, SPORT, AND WORK PHYSIOLOGY
Division of Health and Physical Education
Virginia Polytechnic Institute and State University

Informed Consent

Title of Study: The Elevation of Metabolic Rate after Combined Arm and Leg versus Leg Only Exercise

Purpose of Study: Exercise has been determined to be an important adjunct to weight loss programs. It is the purpose of this study to determine if combined arm and leg exercise or leg only exercise is more beneficial to weight loss programs in terms of caloric expenditure during and after exercise.

Study Requirements:

1. Completion of a detailed medical history form including information such as family history of heart disease and hypertension (high blood pressure), any personal past or present illness, injuries, or health related problems requiring medical attention, and current exercise habits.

2. Performing a maximal aerobic exercise capacity test (ie., a progressive exercise test which requires the subject to attain the point of maximal physical exertion) on a cycle ergometer with continuous monitoring of physiologic parameters (heart rate, blood pressure, perceived exertion, and expired gases).

3. Performing two controlled exercise sessions on two separate days in random order. Exercise sessions to consist of either combined arm and leg or leg only exercise with the same physiologic parameters monitored as before. Also, a required one hour rest period after exercise for continued monitoring.

4. Abstaining from exercise, food, beverages, tobacco, and analgesics for predesignated durations prior to each experimental session.

5. Having an estimation of body composition using the techniques utilizing skinfold measurements and hydrostatic weighing. The skinfold technique involves the measurement of pinches of skin and subcutaneous fat at selected sites on the body. Hydrostatic weighing is a procedure of whole body immersion and weighing so as to determine the buoyancy of the body.

Risks Associated with Participation:

This study will be supervised by Dr. Reed Humphrey, an American College of Sports Medicine certified Preventive and Rehabilitative Exercise Specialist and Program Director, and conducted by Lesley Retallick and Stuart Lee, second-year graduate students in exercise physiology experienced in exercise testing. The protocols for this investigation have been reviewed by a committee of faculty members in exercise physiology and approved by the Human Subjects Committee of the Division of Health and Physical Education and the Institutional Review Board of the university. Although all procedures will be performed by trained technicians under laboratory conditions, there is always the possibility of adverse effects due to participation in this study. Possible risks and discomforts include, but are not limited to, strains, sprains, fractures, delayed muscle soreness, infections, and even the remote possibility of death. Other types of injury may occur, but it is not possible to specifically state each and every individual risk. A standardized emergency protocol is established in the Laboratory for Exercise, Sport, and Work Physiology to notify and secure prompt medical services. However, no direct medical treatment or compensation is available if injury is incurred. It is understood that the subjects reserve the right to abstain from participation in any part of this experiment or withdraw from the experiment should she feel that the activities may be injurious to her health.

All subjects will be requested to complete a medical history form. It is the subject's responsibility to advise the researchers of any pre-existing or current medical problem that may affect her participation. Based upon the subject's responses to the medical history form, the experimenter reserves the right to terminate a subject's participation should the experimenter feel that the activities may be injurious to the subject's well-being. It is also the subject's responsibilty to notify the experimenter of any discomforts, injuries, or any adverse experiences during the course of the experiment. All subjects will be debriefed by the experimenter at the completion of the study.

Benefits Associated with Participation:

Subjects may request feedback regarding their aerobic fitness level based upon their maximal exercise test. Information may also be requested regarding a target heart rate range for aerobic exercise training based upon the the information gathered during this study. Prediction of body composition and resting metabolic rate may also be available.

Confidentiality:

I understand that any data of a personal nature will be held in confidence and will be used for research purposes only. I also understand that this may only be used when not identifiable with my person.

I have read and understood the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Signature:________________________________ Date:__________

Witness:_________________________________ Date:__________

Project Coordinators: Lesley Retallick and Stuart Lee (552-5169/231-5006)
HPE Human Subjects Chairperson: Dr. Charles Baffi (231-8284)
University Human Subjects Chairperson: Dr. Ernie Stout (231-5281)

APPENDIX C

Rating of Perceived Exertion

Instructions

INSTRUCTIONS FOR USING THE BORG SCALE FOR RATING PERCEIVED EXERTION

During the exercise session we want you to pay close attention to how hard you feel the work rate, or intensity, is. This feeling should be your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath, or exercise intensity, but try to concentrate on your total, inner feeling of exertion.

You will be asked to rate this overall feeling on a numerical scale. A technician will present the scale periodically during exercise, and you will be asked to point to a number which represents how hard you feel the work rate is. This is a subjective response. There are no incorrect answers. Don't underestimate or overestimate, just be as accurate as you can.

APPENDIX D

Borg

Rating of Perceived Exertion

Scale

BORG 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 E

Health History and

Activity Form

HEALTH STYLE QUESTIONNAIRE

Name:_____________________________
ID#:________________________

Sex:______ Age:____________ Phone
#:____________________

MEDICAL HISTORY

Have you ever had:	YES	NO
Heart Disease or heart problems	_____	_____
Lung disease or difficulty breathing	_____	_____
Difficulty with cold hands or feet	_____	_____
Stroke	_____	_____
Kidney disease	_____	_____
High cholesterol	_____	_____
High triglycerides	_____	_____
Diabetes	_____	_____
Raynaud's Syndrome	_____	_____
Any operations (Type/Date)	_____	_____
________________________________/_______		
________________________________/_______		
________________________________/_______		
Have you ever had a blood pressure reading above normal (140/90)?	_____	_____
Have you ever been diagnosed as having hypertension?	_____	_____

Please list any medications which you are currently taking:____
____

Are you allergic to any medications, drugs, or foods? If so, please list.____
____

Has anyone in your family been diagnosed as having:

	YES	NO	RELATIONSHIP	AGE AT ONSET
High blood pressure/hypertension	__	___	____________	____
Heart disease or heart attack	__	___	____________	____

Stroke	__	___	____________	____
Diabetes	__	___	____________	____
Kidney disease	__	___	____________	____

HEALTH HABITS

	YES	NO	
Drink caffeinated tea, coffee, or soda	_____	_____	
_____cups/days			
Drink alcohol	_____	_____	
_____drinks/day			
Add salt to meal before tasting	_____	_____	_____
Smoke cigarettes	_____	_____	
_____cigs/day			
Sleep		_____hours/night	

EXERCISE HABITS

During the past 3 months, have you engaged in any regular (3 times/week) physical exercise? _____Yes _____No

If yes, please list below any activities in which you engaged in an average week over the past month (Please include competitive, recreational, or leisure time activities). Also, include frequency and duration (or number of laps, miles, sets, games, etc.) of the activity and PLEASE BE AS SPECIFIC AS POSSIBLE!!

ACTIVITY	FREQUENCY	DURATION
1.___________________	___________________	___________________
2.___________________	___________________	___________________
3.___________________	___________________	___________________
4.___________________	___________________	___________________
5.___________________	___________________	___________________

Do you have any orthopedic problems which may restrict your ability to participate in exercise sessions consisting of stationary cycling or combined arm and leg exercise?

YES_____ NO_____

If yes, please explain:____

The testing for this study will take place any day of the week, depending on your availability and that of the investigators. We will make every effort possible to meet the needs of your schedule. Please assist us by listing below times that you are **not** available to be scheduled for testing.

____
____
____
____

This study requires that you refrain from food, beverages (except water), tobacco products, and analgesics (aspirin, etc.) for up to four hours prior to all exercise sessions. You will also be asked to refrain from exercise for 48 hours prior to testing. Do you feel willing and capable to abide by these requests?

Yes_____ No_____

If no, please explain:____
____

APPENDIX F

Request to Human Subjects Committee

REQUEST FOR APPROVAL OF
INVESTIGATION INVOLVING HUMAN SUBJECTS

Principal Investigator(s) Lesley A. Retallick   Department HPE

Project Title Ratings of Perceived Exertion Using Leg-Only versus Arm-and-Leg Ergometry in College-Age Females

Source of Support: Departmental Research [XX] Sponsored Research [ ] Proposal No. ____

1. The criteria for "expedited review" by the Institutional Review Board for a project involving the use of human subjects and with minimal risk* is one or more of the following. Please initial all applicable conditions and provide a substantiating statement of protocol.

[ ] a. Collection of:

1) hair or nail clipping in a non-disfiguring manner;
2) deciduous teeth;
3) permanent teeth if patient care indicates need of extraction.

[ ] b. Collection of excreta and external secretions: sweat, uncanulated saliva, placenta removed at delivery, amniotic fluid obtained at time of rupture of the membrane.

[XX] c. Recording of data from subjects 18 years or older, using noninvasive procedures routinely employed in clinical practice. Exemption does not include exposure to electromagnetic radiation outside the visible range.

[ ] d. Collection of blood samples by venipuncture (not exceeding 150 ml/8 week period, and no more than twice a week) from subjects 18 years or older, in good health and not pregnant.

[ ] e. Collection of supra- and subgingival dental plaque and calculus, provided the procedure is no more invasive than routine scaling of the teeth.

[ ] f. Voice readings.

[ ] g. Moderate exercise by healthy volunteers.

[ ] h. Study of existing data, documents, records, pathological specimens or diagnostic specimens.

[ ] i. Research on drugs or devices for which an investigational exemption is not required.

2. If the project involves human subjects who are exposed to "more than minimal risk" and are not covered by the criteria above (1 to 9), the IRB review must involve the full IRB board. Please check if the research involves more than minimal risk** __ and provide a substantiating statement of protocol.

3. Human subjects would be involved in the proposed activity as either: Minors and or Children*___, Fetuses___, Abortuses___, Pregnant Women___, Prisoners___, Mentally Retarded___, Mentally Disabled___.

Note that if children are involved in the research as human subjects, they may have to provide consent as well as their parents.

Whether or not the project may undergo "expedited review" or must be reviewed by the full Institutional Review Board, it is necessary that the required informed consent forms also be reviewed. These should be submitted with the proposal. However, if there is insufficient time to meet the sponsor's deadline, submittal can be delayed up to thirty days after submittal of the proposal without jeopardizing the IRB certification to the prospective sponsor.

*Minimal risk means that the risks of harm anticipated in the proposed research are not greater, considering the probability and magnitude, than those encountered in daily life or during performance of routine physical or psychological examinations or tests.

**Subject at risk is an individual who may be exposed to the possibility of injury as a consequence or participation as a subject in any research, development or related activity which departs from the application of those established and accepted methods necessary to meet his needs, or which increases the ordinary risks of daily life, including the recognized risks inherent in a chosen occupation or field of science.

This is to certify that the project identified above will be carried out as approved by the Human Subject Review Board, and will neither be modified nor carried out beyond the period approved below without express review and approval by the Board.

Lesley A Retallick 7/25/1991
Principal Investigator Date

Departmental Reviewer/Date

The Human Subjects Review Board has reviewed the protocol identified above, as it involves human subjects, and hereby approves the conduct of the project for ____ months, at which time the protocol must be resubmitted for approval to continue.

Board Chairman Authorized Reviewer Date

APPENDIX G

Raw Data/Statistical Analysis

TABLE 3. SUBJECT CHARACTERISTICS

Subject	Age (yrs)	Weight (kg)	Percent Body Fat
1	21	59.8	25.9
2	22	68.2	24.2
3	22	57.8	20.4
4	21	71.7	21.1
5	20	64.3	27.3
6	20	53.1	15.8
7	22	57.1	25.1
8	21	60.4	25.9
9	19	56.3	25.0
10	20	54.5	19.9
11	24	59.1	17.5
12	21	66.6	25.2
13	20	59.1	21.4
14	23	60.0	23.7
15	20	56.5	24.3
16	20	46.5	10.9
Mean	**21.0**	**59.44**	**22.1**
SE	**0.33**	**1.53**	**1.10**

TABLE 4. RESULTS OF MAXIMAL GRADED EXERCISE TEST

Subject	Max VO_2 (L/min)	Max VO_2 (ml/kg/min)	Target VO_2 (L/min)	Target HR (beats/min)
1	2.57	43.00	1.80	143
2	3.56	52.18	2.49	187
3	2.47	42.81	1.73	172
4	2.86	39.89	2.00	167
5	3.05	47.43	2.14	172
6	2.39	44.98	1.67	156
7	2.54	44.49	1.78	175
8	3.49	57.70	2.44	162
9	2.30	40.81	1.61	176
10	2.32	42.48	1.62	161
11	2.48	41.97	1.74	151
12	2.84	42.64	1.99	178
13	2.41	40.74	1.69	172
14	2.90	48.34	2.03	175
15	2.63	46.55	1.84	174
16	2.09	44.85	1.46	168
Mean	**2.68**	**45.05**	**1.88**	**168.06**
SE	**0.10**	**1.16**	**0.07**	**2.78**

TABLE 5. SUMMARY OF EXERCISE SESSIONS

Variable	Leg-only (LE)	Arm-and-Leg (ALE)	Significance
RPE	13.7 ± 0.2	13.0 ± 0.3	$p < 0.069$
HR (bpm)	172.8 ± 1.2	170.6 ± 1.3	$p < 0.006^{**}$
VO_2 (L/min)	1.82 ± 0.06	1.79 ± 0.05	$p < 0.116$
WORKLOAD (Watts)	120.0 ± 3.83	127.7 ± 4.11	$p < 0.0003^{***}$

Note. Values following ± indicate SE
$^{**}p < 0.01$. $^{***}p < 0.001$

TABLE 6. MEAN EXERCISE SESSION HR & RPE RESPONSES

	Leg-Only (LE)		Arm-and-Leg (ALE)	
TIME	**MEAN HR (bpm)**	**SE**	**MEAN HR (bpm)**	**SE**
5	166.1	2.70	159.5	2.7
10	175.4	2.50	169.4	2.9
15	174.6	3.1	173.1	2.5
20	174.6	3.0	174.3	2.9
25	173.2	3.0	174.0	2.9
30	172.6	2.8	173.2	3.2
Overall Mean	**172.8**	**0.85**	**170.6**	**1.43**

TIME	**MEAN RPE**	**SE**	**MEAN RPE**	**SE**
5	12.1	0.49	10.6	0.43
10	14.0	0.43	12.0	0.52
15	14.0	0.42	13.4	0.66
20	14.4	0.61	14.0	0.67
25	13.5	0.65	13.9	0.60
30	13.1	0.69	13.6	0.66
Overall Mean	**13.5**	**0.20**	**12.9**	**0.33**

TABLE 7. MEAN INDIVIDUAL HR RESPONSES

(beats / min)

Subject	Leg-Only (LE)	Arm-and-Leg (ALE)
1	153.3	150.5
2	184.5	186.7
3	175.7	169.5
4	173.3	168.0
5	181.8	177.2
6	152.3	155.3
7	179.3	173.8
8	169.5	167.7
9	176.3	178.2
10	161.7	161.2
11	156.3	153.0
12	184.8	183.3
13	181.5	180.3
14	177.5	174.2
15	178.8	176.0
16	178.0	174.7
Mean	**172.8**	**170.6**
SE	**0.85**	**1.43**

TABLE 8. MEAN INDIVIDUAL RPE RESPONSES

Subject	Leg-Only (LE)	Arm-and-Leg (ALE)
1	13.8	11.5
2	14.3	12.0
3	11.3	13.7
4	14.2	14.0
5	13.8	13.7
6	9.8	8.7
7	12.7	11.8
8	13.5	15.2
9	16.2	16.8
10	15.3	14.3
11	15.0	13.7
12	12.5	9.3
13	13.0	12.3
14	13.7	14.0
15	14.8	12.5
16	15.8	14.7
Mean	**13.7**	**13.0**
SE	**0.2**	**0.3**

TABLE 9. MEAN INDIVIDUAL VO_2 RESPONSES

(L/min)

Subject	Leg-Only (LE)	Arm-and-Leg (ALE)
1	1.85	1.77
2	2.34	2.23
3	1.69	1.71
4	2.02	1.80
5	2.03	1.90
6	1.40	1.54
7	1.67	1.78
8	2.16	2.09
9	1.60	1.53
10	1.83	1.78
11	1.70	1.69
12	1.74	1.82
13	1.67	1.61
14	1.83	1.76
15	1.84	1.88
16	1.75	1.69
Mean	**1.82**	**1.79**
SE	**0.06**	**0.05**

TABLE 10. MEAN INDIVIDUAL VO_2 RESPONSES

(ml/kg/min)

Subject	Leg-Only (LE)	Arm-and-Leg (ALE)
1	30.5	29.3
2	33.8	32.9
3	30.0	29.9
4	28.4	25.5
5	31.8	29.6
6	26.6	29.3
7	29.2	30.9
8	35.5	33.8
9	28.2	27.0
10	32.9	31.8
11	28.8	28.8
12	26.4	27.1
13	28.6	27.7
14	31.5	29.9
15	32.6	33.0
16	36.9	35.5
Mean	**30.7**	**30.1**
SE	**0.76**	**0.68**

TABLE 11. MEAN EXERCISE SESSION WORKLOADS

(Watts)

Subject	Leg-Only (LE)	Arm-and-Leg (ALE)
1	112.3	106.7
2	143.0	156.7
3	111.2	119.2
4	130.5	130.0
5	134.8	144.2
6	91.7	101.7
7	112.7	126.7
8	147.2	152.5
9	101.3	105.0
10	129.3	132.5
11	108.3	128.3
12	120.8	126.7
13	112.3	110.0
14	123.5	137.5
15	132.3	140.7
16	108.3	124.2
Mean	**120.0**	**127.7**
SE	**3.83**	**4.11**

Table 12: Raw Data from Exercise Sessions

MONARK DATA																		
SUBJECT #		**1**			**2**			**3**			**4**			**5**			**6**	
	HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**
min 5	145	31	13	175	33.61	9	170	31.85	11	160	27.6	13	170	34.41	12	154	28.72	10
min 10	154	30.66	16	183	36.65	13	178	33.26	12	174	32.98	15	182	35.47	15	161	28.98	11
min 15	154	30.42	14	190	37.37	15	179	31.05	12	176	31.87	15	185	33.92	15	150	25.49	10
min 20	157	30.46	14	190	34.61	17	178	28.91	12	180	28.59	16	184	30.57	14	153	26.48	10
min 25	153	30.65	13	184	29.81	15	176	27.01	11	175	24.97	13	185	30.31	14	146	24.87	9
min 30	157	30.02	13	185	30.64	17	173	27.87	10	175	24.53	13	185	26.31	13	150	24.95	9
Mean HR	153.3			184.5			175.7			173.3			181.8			152.3		
Mean VO2		30.5			33.8			30.0			28.4			31.8			26.6	
Mean RPE			13.8			14.3			11.3			14.2			13.8			9.8

AIRDYNE DATA																		
SUBJECT #		**1**			**2**			**3**			**4**			**5**			**6**	
	HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**
min 5	147	32.69	8	176	32.35	9	155	25.42	10	155	24.39	12	155	24.48	11	151	28.52	8
min 10	155	36.73	10	186	35.28	11	168	29.74	12	161	25.53	14	171	27.21	12	152	28.79	8
min 15	156	30.07	12	192	36.24	13	170	31.11	14	172	27.28	14	178	31.52	14	157	29.65	8
min 20	153	27.36	13	190	33.83	13	174	30.73	16	175	26.02	15	183	31.32	15	150	28.12	9
min 25	147	25.59	13	189	29.9	13	176	32.08	15	171	25.18	15	187	31.99	15	165	31.37	10
min 30	145	23.48	13	187	29.8	13	174	30.38	15	174	24.77	14	189	31.17	15	157	29.44	9
Mean HR	150.5			186.7			169.5			168.0			177.2			155.3		
Mean VO2		29.3			32.9			29.9			25.5			29.6			29.3	
Mean RPE			11.5			12.0			13.7			14.0			13.7			8.7

Table 12 (continued): Raw Data from Exercise Sessions																	
MONARK DATA																	
	7			**8**			**9**			**10**			**11**			**12**	
HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**
170	30.18	13	155	35.7	13	172	30.96	14	149	32.42	9	162	34.31	13	181	30.67	16
180	30.98	13	171	37.8	14	180	31.84	17	167	36.18	13	161	31.08	15	186	30.27	16
182	31.21	13	180	36.72	15	176	26.79	15	168	36.23	16	151	26.4	16	187	28.53	13
182	29.08	13	172	37.77	15	177	26.77	17	161	31.02	18	152	26.8	17	187	24.56	11
180	27.06	12	172	34.91	13	180	28.91	18	165	32.77	18	154	27.21	15	183	21.59	10
182	26.91	12	167	30.31	11	173	23.93	16	160	28.8	18	158	27.15	14	185	22.58	9
179.3			169.5			176.3			161.7			156.3			184.8		
	29.2			35.5			28.2			32.9			28.8			26.4	
		12.7			13.5			16.2			15.3			15.0			12.5
AIRDYNE DATA																	
	7			**8**			**9**			**10**			**11**			**12**	
HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**
163	30.94	12	160	34.15	12	165	26.45	12	147	28.87	10	140	26.59	13	179	29.37	10
176	32.33	12	169	35.95	15	178	29.92	15	162	36.17	13	150	29.28	13	184	28.91	9
173	31.37	12	170	35.69	17	179	27.2	18	167	36.13	15	157	31.36	14	185	27.6	9
180	33.39	12	170	34.41	17	184	27.4	19	165	30.89	16	162	29.65	14	185	27.11	10
178	30.35	12	170	31.87	16	181	25.65	18	162	28.34	16	155	29.04	14	183	24.83	9
173	27.22	11	167	30.9	14	182	25.26	19	164	30.6	16	154	26.65	14	184	24.76	9
173.8			167.7			178.2			161.2			153.0			183.3		
	30.9			33.8			27.0			31.8			28.8			27.1	
		11.8			15.2			16.8			14.3			13.7			9.3

Table 12 (continued): Raw Data from Exercise Sessions

MONARK DATA

13			14			15			16				Means:				SE:		
HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**		**HR**	**VO2**	**RPE**		**HR**	**VO2**	**RPE**
178	32.46	11	173	32.74	13	176	37.36	15	173	39.24	13	min 5	166.4	32.7	12.4		2.72	0.76	0.49
186	32.6	13	182	35.29	13	182	38	16	180	41.52	17	min 10	175.4	34.0	14.3		2.46	0.86	0.45
178	26.98	13	176	32.11	14	182	32.73	16	180	37.74	17	min 15	174.6	31.6	14.3		3.12	1.01	0.44
183	27.39	13	181	31.38	14	178	29.59	14	178	34.5	17	min 20	174.6	29.9	14.5		3.02	0.86	0.59
182	27.16	14	178	29.99	14	180	29.89	15	178	33.78	16	min 25	173.2	28.8	13.8		3.03	0.87	0.63
182	24.86	14	175	27.31	14	175	28.2	13	179	34.43	15	min 30	172.6	27.4	13.2		2.78	0.75	0.65
181.5			177.5			178.8			178.0										
	28.6			31.5			32.6			36.9									
		13.0			13.7			14.8			15.8								

AIRDYNE DATA

13			14			15			16				Means:				SE:		
HR	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**	**HR**	**VO2**	**RPE**		**HR**	**VO2**	**RPE**		**HR**	**VO2**	**RPE**
174	30.6	9	157	22.87	13	167	33.32	12	161	30.57	12	min 5	159.5	28.8	10.8		2.74	0.87	0.42
187	30.42	11	167	27.97	13	173	34.73	14	172	35.96	14	min 10	169.4	31.6	12.3		2.86	0.93	0.51
182	27.31	13	177	31.66	14	177	33.49	13	178	39.84	16	min 15	173.1	31.7	13.5		2.55	0.93	0.64
177	26.08	13	179	32.4	14	181	34.62	13	181	38.47	16	min 20	174.3	30.7	14.1		2.87	0.9	0.64
178	25.78	14	181	32.15	15	180	32.47	12	181	36.08	15	min 25	174.0	29.5	13.9		2.91	0.84	0.58
184	26.04	14	184	32.51	15	178	29.32	11	175	32.34	15	min 30	173.2	28.4	13.6		3.19	0.73	0.65
180.3			174.2			176.0			174.7										
	27.7			29.9			33.0			35.5									
		12.3			14.0			12.5			14.7								

STATISTICAL ANALYSES

I. RPE ANALYSES

A. UNIVARIATE REPEATED MEASURES ANOVA

Table 12. RPE REPEATED MEASURES ANOVA

Source	df	SS	MSE	F	p-value
A (mode)	1	25.5208	25.5208	3.83	0.0693 (-----)
error	15	99.9792	6.6653		
B (time)	5	143.25	28.65	10.29	0.0001 (0.0016)
error	75	208.9167	2.7856		
AB	5	36.1042	7.2208	7.18	0.0001 (0.0027)
error	75	75.3958	1.0053		

Note. Values in parentheses are Huyn-Feldt's adjusted p-value.

B. MULTIPLE COMPARISONS

Response	Effect	Tukey's
RPE	Mode	--------
	time	20, 15, 25, 30, 10/5

C. SIMPLE EFFECTS

1. By Time

Time	Mode Effect	Tukey's
5	0.0038	Monark/Airdyne
10	0.0014	Monark/Airdyne
15	0.1026	
20	0.3873	
25	0.7915	
30	0.5033	

2. By Mode

Mode	Time Effect	Tukey's
Airdyne	0.0001	20,25,30,15/10/5
Monark	0.0019	20,15,10,25,30/25,30,5

D. UNIVARIATE ANALYSES ON PAIRED DATA

1. Tests of Paired Times

a. All Data Combined
(Bonferroni's correction with 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
RPE	5-10	.0001	.0001	.0001	.0341
	5-15	.0001	.0001	.0001	.4566
	5-20	.0001	.0001	.0001	.4511
	5-25	.0002	.0009	.0001	.3814
	5-30	.0048	.0428	.0024	.4649
	10-15	.0210	.0266	.0249	.0226
	10-20	.0101	.0094	.0061	.3362
	10-25	.1901	.2649	.1185	.2133
	10-30	.8451	1.000	.7306	.2830
	15-20	.0374	.0213	.0567	.0003
	15-25	.6870	.6900	.6787	.0922
	15-30	.0842	.7011	.0849	.0142
	20-25	.0138	.0525	.0119	.0054
	20-30	.0002	.0009	.0001	.0124
	25-30	.0083	.0074	.0141	.0002

b. Airdyne Only
(Bonferroni's correction with 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
RPE	5-10	.0004	.0063	.0015	.0213
	5-15	.0001	.0018	.0006	.2184
	5-20	.0001	.0001	.0001	.1359
	5-25	.0001	.0018	.0004	.3168
	5-30	.0006	.0213	.0009	.3740
	10-15	.0005	.0063	.0020	.0141
	10-20	.0001	.0010	.0004	.4149
	10-25	.0005	.0018	.0018	.0159
	10-30	.0155	.0574	.0228	.2073
	15-20	.0028	.0078	.0078	.0005
	15-25	.1108	.2266	.1826	.0277
	15-30	.8425	.3877	.8184	.0011
	20-25	.3332	.5078	.5078	.0033
	20-30	.0719	.1797	.1172	.0430
	25-30	.0962	.2188	.1875	.0021

c. Monark Only
(Bonferroni's correction wfth 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
RPE	5-10	.0001	.0002	.0002	.0964
	5-15	.0053	.0018	.0057	.2470
	5-20	.0212	.0129	.0148	.2762
	5-25	.1208	.2266	.0889	.2485
	5-30	.4036	.7905	.4362	.0952
	10-15	1.000	1.000	1.000	.2825
	10-20	.7534	1.000	.8672	.3627
	10-25	.3621	.3018	.2627	.2214
	10-30	.1351	.0768	.0908	.0733
	15-20	.5489	.7266	.6875	.0332
	15-25	.1554	.0574	.1371	.0292
	15-30	.0312	.1185	.0422	.2415
	20-25	.0228	.0923	.0327	.1839
	20-30	.0011	.0034	.0020	.4152
	25-30	.0454	.0391	.0781	.0188

2. Tests of Exercise Modality

a. Modality Effect, by Time
(Bonferroni's correction wfth 6 comparisons yields alpha=.05/6=.0083)

Response	TIME	Paired T	Sign	WSR	S-W
RPE	5	.0038	.0034	.0020	.0220
	10	.0014	.0034	.0010	.0700
	15	.1026	.0574	.1515	.2135
	20	.3873	.1796	.3894	.2167
	25	.7915	1.000	.8989	.7426
	30	.5033	.7539	.5234	.5636

Note. 'Paired T' stands for the p-values in a paired t-test,'Sign' stands for the Sign test, 'WSR' stands for the Wilcoxon Signed Rank test, and'S-W' stands for the Shapiro-Wilk test for normality.

II. HR ANALYSES

A. UNIVARIATE REPEATED MEASURES ANOVA

Source	df	SS	MSE	F	p-value
A (mode)	1	234.0833	234.0833	10.25	0.0059 (-----)
error	15	342.4167	22.8278		
B (time)	5	3007.0417	601.4083	36.09	0.0001 (0.0001)
error	75	1249.7917	16.6639		
AB	5	465.8542	93.1708	5.97	0.0001 (0.0027)
error	75	1169.6458	15.5953		

Note. Values in parentheses are Huyn-Feldt's adjusted p-value.

B. MULTIPLE COMPARISONS

Response	Effect	Tukey's
HR	Mode	Airdyne/Monark
	time	20, 15, 25, 30, 10/5

C. SIMPLE EFFECTS

1. By Time

Time	Mode Effect	Tukey's
5	0.0020	Monark/Airdyne
10	0.0005	Monark/Airdyne
15	0.2825	
20	0.8264	
25	0.5759	
30	0.6753	

2. By Mode

Mode	Time Effect	Tukey's
Airdyne	0.0001	20,25,30,15/30,15,10/5
Monark	0.0001	10,15,20,25,30/5

D. UNIVARIATE ANALYSES ON PAIRED DATA

1. Tests of Paired Times

a. All Data Combined

(Bonferroni's correction with 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
HR	5-10	.0001	.0001	.0001	.7054
	5-15	.0001	.0001	.0001	.4556
	5-20	.0001	.0001	.0001	.7122
	5-25	.0001	.0001	.0001	.4743
	5-30	.0001	.0001	.0001	.3051
	10-15	.1456	.0081	.0890	.1946
	10-20	.0777	.1496	.0977	.6930
	10-25	.3397	.7111	.4515	.5304
	10-30	.7192	1.000	.9389	.0576
	15-20	.4248	.4421	.3384	.1065
	15-25	.7179	.3616	.7858	.6584
	15-30	.2705	.2478	.2810	.8520
	20-25	.2659	.1849	.0840	.0026
	20-30	.0427	.0081	.0379	.0294
	25-30	.2655	1.000	.2954	.4428

b. Airdyne Only

(Bonferroni's correction wfth 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
HR	5-10	.0001	.0001	.0001	.5854
	5-15	.0001	.0001	.0001	.3683
	5-20	.0001	.0005	.0001	.3803
	5-25	.0001	.0001	.0001	.5186
	5-30	.0001	.0005	.0001	.6076
	10-15	.0039	.0042	.0038	.6962
	10-20	.0082	.0213	.0088	.5282
	10-25	.0228	.0352	.0226	.7537
	10-30	.0594	.1185	.0428	.3206
	15-20	.2595	.4240	.2377	.3426
	15-25	.4928	1.000	.4615	.9574
	15-30	.9614	1.000	.9368	.7431
	20-25	.8066	.4240	.3713	.0083

20-30	.3889	.1185	.3071	.1095
25-30	.3926	.8036	.4733	.8579

c. Monark Only

(Bonferroni's correction wfth 15 comparisons yields alpha=.05/15=.0033.)

Response	DIFF	Paired T	Sign	WSR	S-W
HR	5-10	.0001	.0005	.0001	.2807
	5-15	.0024	.0074	.0036	.9987
	5-20	.0005	.0042	.0012	.5882
	5-25	.0024	.0042	.0060	.1282
	5-30	.0017	.0213	.0036	.2219
	10-15	.5727	.5811	.7742	.2645
	10-20	.4546	1.000	.4638	.9106
	10-25	.0483	.1796	.0220	.0039
	10-30	.0177	.2101	.0251	.2696
	15-20	.9489	1.000	.9080	.2591
	15-25	.1139	.1185	.1703	.6028
	15-30	.1151	.0923	.1213	.8238
	20-25	.1167	.4240	.1329	.8526
	20-30	.0231	.0574	.0306	.1230
	25-30	.4973	1.000	.4434	.1660

2. Tests of Exercise Modality

a. Modality Effect, by Time

(Bonferroni's correction with 6 comparisons yields alpha=.0516=.0083.)

Response	Time	Paired T	Sign	WSR	S-W
HR	5	.0020	.0213	.0017	.8245
	10	.0005	.0213	.0009	.5239
	15	.2875	.8036	.3525	.5323
	20	.8264	.3018	.7089	.1140
	25	.5759	1.000	.9893	.0012
	30	.6753	.6072	.5499	.5226

Note. 'Paired T' stands for the p-values in a paired t-test,'Sign' stands for the Sign test, 'WSR' stands for the Wilcoxon Signed Rank test, and'S-W' stands for the Shapiro-Wilk test for normality.

III. ADDITIONAL ANALYSES

A. PAIRED T-TESTS: VO_2 (ml/kg/min)

File: Mean V02.stat   size: 17 * 5 MISS = -9999.00
Include all cases

STATISTICA BASIC STATISTICS   T-Test for Dependent Samples
Missing Data Pairwise Deleted

Variables	t	df	p
MONREL -AIRREL	1.6687	15	.11592

B. PAIRED T-TESTS: VO_2 (L/min)

File: Mean V02.stat size: 17 * 5 MISS=-9999.00
Include all cases

STATISTICA BASIC STATISTICS — T-Test for Dependent Samples, Missing Data Pairwise Deleted

Variables		t	df	p
MONABS	-AIRABS	1.4738	15	.16121

C. DESCRIPTIVE STATISTICS

File: Mean V02.stat size: 17 * 5 MISS = -9999.00
Include all cases

STATISTICA BASIC STATISTICS — Descriptive Statistics, N of Cases = 17

Variable	N	Min	Max	Mean	Std.Err.	Std.Dev.
MONREL	16	26.3700	36.9000	30.7369	.76274	3.0510
AIRREL	16	25.5300	35.5000	30.1331	0.6814	2.7258
MONABS	16	1.4008	2.3409	1.8213	0.0570	0.2280
AIRABS	16	1.5271	2.2339	1.7865	0.0455	0.1819

STATISTICA BASIC STATISTICS — Descriptive Statistics, N of Cases = 17

Variable	Skewness	Kurtosis
MONREL	0.5016	-0.4084
AIRREL	0.2983	-0.4277
MONABS	0.6399	0.8751
AIRABS	0.9990	1.5382

IV. POWER CALCULATIONS FOR H_0 ACROSS EXERCISE SESSIONS

Assuming normal distribution of RPE, and a two-sided test:

$n = 16$

Std. Dev. = 2.1102

Effect size (d) = 0.4739 (1 RPE rating point)

Power = 0.4091

ß = 0.5909

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