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Influence of Cardiovascular Condition of Women on Perceived Exertion during Submaximal Workloads

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INFLUENCE OF CARDIOVASCULAR CONDITION

OF WOMEN ON PERCEIVED EXERTION

DURING SUBMAXIMAL WORKLOADS

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

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ABSTRACT

Perceived exertion has been identified as the subjective estimation of the work intensity (Morgan, 1973). With an increase in popularity of exercise, an awareness for safety is necessary. A scale presented by Borg (1962) was designed to help quantify a person's perception of work. This scale was later revised to improve its accuracy as a tool for perceiving effort. The intent of this study was to investigate the relationship between perceived exertion and excerise in women. The purpose of this study was to determine if the cardiovascular condition of college age women affects their ability to perceive efforts of work on a bicycle ergometer and a motor-driven treadmill under normal conditions. Twenty college age females were used as subjects. Trial 1 (T_1) was used to determine max HR values and VO_2 to identify their condition. Trial 2 (T_2) consisted of three submaximal workloads equaling 20%, 60% and 85% of each subject's HR reserve (HRR) calculated using the Karvonan principle. Results of this study indicated that college age females who are in better cardiovascular condition can perceive effort more accurately than unconditioned females of the same age. It was also concluded that as work levels increase, the accuracy of ratings of perceived exertion (RPE) increase. Once the level of effort on the bicycle ergometer or treadmill reached 60% HRR for the conditioned group, their subjective ratings of effort were good. The level of effort for the unconditioned group has to approach the 85% HRR mark in order for RPE to be an accurate predictor of effort and HR.

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CHAPTER I

INTRODUCTION

Physical exercise is quite complex and involves a number of components. As stated by Astrand and Rodahl (1977) human performance has three main divisions: (1) energy output which is made up of aerobic and anaerobic processes and oxygen transport, (2) neuromuscular function including muscle strength, coordination, and technique, and (3) psychological factors, such as motivation, tactics and perception of effort.

The concept of perceived exertion is one element of these psychological factors that warrants additional study. As defined by Morgan (1973, p. 97) perceived exertion is "one's subjective estimation of the intensity of the work being performed." With the increased popularity of physical activity for preventive or rehabilitative purposes, an increase in awareness for safety and effectiveness is necessary. This then, would demand a better understanding as to how the exercising subject is doing or rather at what capacity they think they are performing. Used in some laboratory settings, perceived exertion of these patients enabled them to work in the absence of equipment or medical personnel. Borg (1970) stated that people's estimation of work intensity should not be underestimated. Perceived exertion was determined to be a major factor directly relating a worker's response to adaptation and motivation (Borg, 1962).

A scale presented by Borg in the early 1960s was designed to quantitatively measure a person's perception of work. The task of the subjects was to assign a number from one to twenty that represented the subject's sensation of work being done. This made it possible to develop comparisons between individuals. Later a revised scale ranging from six to twenty was determined to be a valid measuring tool for perception of effort during work (Borg, 1973).

Perceived exertion has been determined to be subjective, personal, and extremely complex (Morgan, 1973). More recent studies have tried to identify how environmental factors such as altitude, temperature, and humidity affect perceived exertion. Others have focused on specific items that may influence a person's perceptual mechanism. For example, Pandolf (1978) found that central and local sensory cues were factors influencing perception of effort. Central cues are cardiovascular in nature, such as heart rate, and local cues are concentrations of metabolites, muscular discomfort, or a general feeling of strain in the working muscles and/or joints.

The concept of perceived exertion, while increasing in popularity, still leaves many questions unanswered. Research identifying different modes of exercise and their relationships to perceived exertion need further inquiry. Accuracy of perceived exertion between groups of skilled and unskilled, trained and untrained, men and women, would promote a better understanding of one's perception of effort. The intent of this study was to further investigate the relationship between perceived exertion and exercise in women.

Purpose of the Study

The primary purpose of this study was to determine if the cardiovascular condition of college age women affected their ability to accurately predict heart rate at a variety of workloads using Borg's RPE scale.

A secondary purpose was to determine what effects different levels of work and cardiovascular condition had on the accuracy of RPE.

Significance of the Study

In reviewing the literature on perceived exertion, there was a lack of information concerning how women perceive effort. Most studies have used male subjects. It is quite possible that women perceive effort differently from men, as show by Henriksson, Knuttgen and Bonde-Peterson (1972). They concluded that females perceive the effort involved in eccentric and concentric muscle contractions higher than males. In studies by Arstila, Antila, Wendelin, Vuori and Valimaki (1977, p. 217) and Borg and Linderholm (1970, p. 194), differences were noted in heart rate perceived exertion (HR-RPE) relationships between men and women. Although the differences in the latter two studies were notably small, they suggest that more information of this type would help clarify how sex might influence perceived exertion of a given workload. Thus, previous information using male subjects may or may not apply to both sexes.

Hypothesis

It was hypothesized that:

1. College age women who are in better cardiovascular condition were able to perceive levels of work more accurately than noncardiovascular conditioned women of the same age.

2. Cardiovascular conditioned women of college age were able to reproduce a given HR using RPE as the means of

judgment, better than noncardiovascular conditioned women of the same age.

3. Ratings of perceived exertion were more accurate at higher workloads than at lower workloads in females of college age.

Assumptions

The following assumptions were made for this study:

1. Recordings from the ECG unit used to measure HR were reliable.

2. The electronically braked bicycle ergometer was accurate and reliable for controlling work output.

3. The subjects complied with the investigator's request for exerting maximal effort to achieve maximal HR.

Limitations

This study was limited to the following:

1. Caution must be given to the generalization of the findings due to the limited number of trials and limited number of subjects.

2. Subject's perception of effort could vary due to the many influencing cues of the body on RPE.

3. Previous experience on a bicycle was not controlled.

4. The subjects had no previous exposure to Borg's (RPE) scale.

5. Daily activities were not restricted, so it was possible that the degree of effort perceived was influenced by fatigue from outside activities.

Delimitations

The following delimitations were identified for this study:

1. The sample size was limited to 20 college age female subjects.

2. All subjects were volunteers from the University of Northern Iowa campus.

3. The present study dealt only with perceived exertion at submaximal workloads that were determined by a percent of maximum HR.

4. The Borg 15-point scale of perceived exertion was used for all subjective ratings of work.

5. The electronically braked ergometer and motor driven treadmill were used as the modes of exercise, in a laboratory setting.

Definition of Terms

The following terms were defined for this study:

Heart rate (HR). Heart rate is the number of ventricular beats per minute as determined by a six-second ECG recording in modified "V5" position.

Rate of Perceived Exertion (RPE). RPE is the rating of perceived exertion as defined by Morgan (1973, p. 97) as "one's subjective estimation of the intensity of the work being performed."

Borg's rating scale of perceived exertion (RPE scale). Borg's method is a means of expressing RPE in a numerical scale ranging from six to twenty with descriptive phrases printed adjacent to every odd number (Borg, 1970, see Figure 1, Chapter II).

Cardiovascular condition. Cardiovascular condition is one's capacity for the utilization of O_2 in an efficient manner. A conditioned female for the purpose of this study was a female with a $\dot{V}O_2$ of 45 ml/Kg.min^{-1} or more and a history of training. An unconditioned female was one with a $\dot{V}O_2$ of 40 ml/Kg.min^{-1} or less and no history of training.

CHAPTER II

REVIEW OF RELATED LITERATURE

The primary purpose of this study was to determine if the cardiovascular condition of college age women affected their ability to accurately predict heart rate at a variety of workloads using Borg's RPE scale. A secondary purpose was to determine what effects different levels of work and cardiovascular condition had on the accuracy of RPE.

The related literature will be presented in the following pattern: (1) history, (2) validity and reliability of Borg's 15-point Rating of Perceived Exertion Scale, (3) heart rate (HR) and RPE, (4) ventilation and RPE, (5) respiration and RPE, (6) combined central and local factors influencing RPE, (7) sex differences and RPE, (8) chemical influences on RPE, and (9) summary.

Historical Background of RPE

Perception of effort may be a kind of "gestalt" or perhaps a combination of many separate sensations and perceptions (Borg, 1977). The concept of rating perceived exertion (RPE) during exercise became an issue in the early 1960s through a series of experiments initiated by Borg (Borg & Dalstrom, 1960; Borg, 1961; Borg, 1961; Borg & Dalstrom, 1962; Borg, 1962; Borg, 1962; cited in Borg, 1962). Borg's intent was to establish a valid and reliable standard for measuring perception of work that could allow for comparisons between individuals.

A process of measuring intensity of effort was first established by Stevens (1957) and then refined by Borg (1962). These studies produced ratio estimations and ratio productions based on the difference between two stimuli. Estimating one workload of a progressive test to the previous workload is an example of ratio estimation. In ratio production, the resistance of the bicycle ergometer had to be adjusted to meet a given multiple of a standard workload, i.e. ½ or 2, etc. (Borg, 1962).

The responses from the psychophysical ratio scaling methods quantify symptoms and apply them to a power function. $R = a + c(c - b)^n$ (Stevens, 1960, cited in Borg, 1982) where R is the intensity of the perception, S is the intensity of the stimulus, a and b are constants showing the absolute threshold, or starting function, and n is the exponent obtained when the RS values were plotted.

The first psychophysical experiments using ratio estimation and ratio production (Borg, 1962) showed a positive accelerating power function of 1.6 for the perception of effort with a reliability of $r = .95$. These results were in agreement with Stevens (1959, cited in Borg, 1982) who found a power function of 1.7 for perception of hand grip strength and Eisler (1961, cited in Borg, 1973) who found an exponent of 1.6 for perception of isometric leg force.

Although ratio scaling methods were useful, they had certain shortcomings. The psychophysical methods cannot be used for interindividual comparisons. This inadequacy generated a more practical method for measuring perception of effort. The result was a 21-point scale (Borg, 1962; see Figure 1) that allowed direct interindividual comparisons of perceived exertion (RPE).

ORIGINAL 21-POINT RPE SCALE

1	
2	
3	EXTREMELY LIGHT
4	
5	VERY LIGHT
6	
7	LIGHT
8	
9	RATHER LIGHT
10	
11	NEITHER LIGHT NOR LABORIOUS
12	
13	RATHER LABORIOUS
14	
15	LABORIOUS
16	
17	VERY LABORIOUS
18	
19	EXTREMELY LABORIOUS
20	
21	

Figure 1. A scale for perceived exertion (Borg, 1962, p.39).

This scale was found to have a high correlation of r = .83 (Borg, 1962) between HR and RPE. By comparing the RPE to working capacity this scale became a useful tool in estimating working capacities (PWC_R) (Borg & Lindholm, 1967).

A revision of the original 21-point scale to a 15-point scale (Borg, 1970; see Figure 2) was aimed at increasing the linear proportionality of RPE to HR. With this new rating scale "the heart rate should be about ten times the RPE value" (Borg, 1973, p. 91). Now the scale became useful in regulating people's work intensity, taking into consideration exertion, fatigue, discomfort, pain, respiratory functions, etc. quantitatively. The Borg 15-point scale is the "single best test for evaluating intensity during exercise" (Hage, 1981, p. 13).

Additional research has shown the Borg rating scale to be very useful for applied studies, exercise testing, predicting work capacity and exercise prescription (Borg, 1982).

Validity and Reliability of Borg's 15-point Rating Scale for Perceived Exertion

Borg (1973) compared HR to RPE for his scale numbered from 6-20 and concluded its correlations of r = .62 and r = .72 were better than three other scales which included his old 21-point scale (r = .56 and r = .60), a 9-point scale (r = .54 and r = .52), and a line scale (r = .61 and r = .69). Although all scales showed adequate correlations with HR-RPE, the 15-point scale was chosen for convenience and consistency since RPE values represent approximately one-tenth of the actual heart rate measured.

BORG 15-POINT SCALE

6	
7	<u>VERY</u> <u>VERY</u> <u>LIGHT</u>
8	
9	<u>VERY</u> <u>LIGHT</u>
10	
11	<u>FAIRLY</u> <u>LIGHT</u>
12	
13	<u>SOMEWHAT</u> <u>HARD</u>
14	
15	<u>HARD</u>
16	
17	<u>VERY</u> <u>HARD</u>
18	
19	<u>VERY</u> <u>VERY</u> <u>HARD</u>
20	

Figure 2. Borg 15-point scale (Borg, 1973)

Validity coefficients were significant and ranged from r = .78 to r = .96 for a randomized test determined by Skinner, Hutsler, Bergsteinova, and Buskirk (1973). They also found no significant difference between tests administered progressively or randomly. They concluded that the 15-point scale was a valid and reliable tool in determining perceived effort regardless of the order in which the workloads were presented.

A study by Morgan (1973) produced similar results. Morgan found the order of presentation of workloads produced no significant differences between ratings of perceived exertion and the actual cost of work. However, he continued to state that any RPE scale did not apply well to subjects who were depressed, neurotic or anxious. A second study by Morgan, Raven, Drinkwater, and Horvath (1973) concluded that an RPE scale was a valid measure of subjective effort when related to all sensory cues with the exception of ventilatory minute volumes.

Stamford (1976) found no significant differences in peak RPE values of 12 submaximal tests that varied in mode of exercise and protocol, regardless when RPE was taken. In view of this, Stamford (1976) concluded the RPE was a valid and reliable measure of work effort independent of preceding ratings.

Komi and Karppi (1977), studying genetic and environmental variations in perceived exertion, found no significant difference between RPE and workload, suggesting that the RPE scale was a valid measure of perceived exertion.

Ulmer, Janz, and Lollgen (1977) showed correlations between RPE and stress and strain were highly significant. For RPE and stress r = .93

and RPE and strain r = .88. The authors concluded from their data that Borg's 15-point scale for ratings of perceived exertion was a valid and reliable measure of stress (load) and strain (HR).

Although the Borg 15-point scale is insensitive to cardiac arhythmias, ST segment depression, oxygen debt and blood pressure changes, it is the "single best test for evaluating intensity of exercise" (Hage, 1981, p. 139).

Borg (1982), after some investigation into a ratio scaling method, emphasizes the ease in which the 15-point scale can be used for applied studies and exercise testing. In a study on clinical applications of RPE by Noble (1982), the author agreed with Borg (1982) and the high correlation between RPE and HR of the 15-point scale. He suggested its use as a valid and reliable measure of work intensity and a good predictor for intensity of training from measures of a graded exercise test.

Several studies have concentrated their efforts on comparing effort sensation between males and females. Noble, Maresh and Ritchey (1981) and Henriksson et al. (1972) found that females perceive effort greater than males when plotted against absolute VO_2 consumption. Noble et al. (1981) then plotted the same data against relative levels of percent O_2 max and found no significant difference between males and females, indicating further research was needed to clarify whether or not a difference actually exists between sexes and their perception of effort.

Heart Rate and RPE

Many studies (Borg, 1962; Borg & Linderholm, 1970; Edwards, Melcher, Hesser, Wigerty, & Ekelund, 1972; Skinner, 1973; Turkulin, Zamlic, & Pegan, 1977) have shown that under normal exercising conditions using normal healthy subjects, HR correlated significantly with RPE. These correlation coefficients ranged from r = .77 to r = .90. In the previous section concerning the history of perceived exertion, it was noted that the initial studies utilized a 21-point scale for rating subjective intensities during exercise (Borg, 1962). HR was found to have a correlation coefficient of r = .83 in a linear fashion. The 21-point scale was later revised to a 15-point scale ranging from 6 to 20, so that the rating chosen corresponded more closely to the actual heart rate measured. This new scale was designed to reflect one-tenth of the actual HR (Borg, 1973).

Significant HR-RPE relationships have been shown with subjects varying in condition and body composition (Ekblom & Goldbarg, 1971; Michael & Eckhardt, 1972; Edwards et al., 1972; Skinner et al., 1973; Doctor & Sharkey, 1971; Dale & Anderson, 1978; Borg, 1977). Doctor and Sharkey (1971) found that progressive training lowered HR and RPE during submaximal workloads. Ekblom and Goldbarg (1971) measured HR and RPE before and after an eight-week training program. When relative HR max and RPE were compared, no significant differences were found. Borg (1977) concluded that trained subjects can perceive effort more accurately than untrained subjects. Similar results were obtained by Dale and Anderson (1978). They showed that subjects with a lower HR and higher stroke volume, due to training, perceived HR changes better than subjects with smaller cardiac outputs. A study by Michael and Eckhardt (1972) required both trained and untrained subjects to choose a workload they considered difficult. Both groups chose work levels equal to 80% of the max HR. Skinner et al. (1973) found no significant differences in relationships between relative max HR and RPE in obese and lean males. These results indicate that HR is a significant factor in determining perception of effort.

Perceived exertion and HR were studied under different working conditions. Stamford (1976) found a significant relationship between HR and RPE during exercise tests of different modes and protocols. Intermittent work was compared to constant work by Edwards et al. (1972). For both types of work, the HR-RPE relationship was very high, suggesting HR was a significant factor in determining RPE. Ekblom and Goldbarg (1971) found that for a given submaximal workload, RPE values were higher for arm work than for leg work. Gamberale (1972) achieved similar results when testing subjects on cycling, lifting weights, and pushing a wheelbarrow. Arm and leg movements were studied by Sargeant and Davis (1973) and they found that HR and RPE values were not closely related for arm movements. RPE values did not correlate well with HR during negative work on a laddermill (Pandolf, Kamon, & Noble, 1978). Ekblom and Goldbarg (1971) found that RPE was higher for a given workload with bicycle work when compared to treadmill exercise. HR was also found to be higher on the bicycle ergometer than on the treadmill for the same RPE (Michael & Hackett, 1972). Stamford and Noble (1974) showed that RPE was higher for a given HR when work on a bicycle was done at 40 rpms compared to 60 rpms. Similar data were obtained by

Lollgen, Ulmer, and Neiding (1977) and Pandolf and Noble (1973). They found that RPE decreased with an increase in pedal speed, showing a negative relationship between RPE and rpms. Others studied the HR-RPE responses of running and walking (Noble, Metz, Pandolf, Bell, Cafarelli, & Sime, 1973). They reported that subjects perceive walking at 4.32 mph more difficult than running at the same submaximal HR even though the net value of work for walking was less than for running.

It was found that RPE did not always follow actual HR under other conditions as well (Ekblom & Goldbarg, 1971; Borg & Linderholm, 1970; Pandolf, 1972; Morgan et al., 1973; Cafarelli & Noble, 1976; Allen & Pandolf, 1977; Turkulin et al., 1977; Karmon, Pandolf, & Cafarelli, 1974; Squires, Rod, Pollock, & Foster, 1982). When HR was altered by autonomic nervous sytem blocking agents during exercise, it no longer correlated significantly with RPE (Ekblom & Goldbarg, 1971; Squires et al., 1982). Pandolf et al. (1973) and Kamon et al. (1974) noted similar results in HR-RPE relationship when HR was altered by heat stress. They found that perceived exertion did not follow changes in HR due to the heat stress. Patients with coronary insufficiencies and/or hypertension had RPE values higher than HR when compared to normal subjects (Borg & Linderholm, 1970). The same was found for subjects who had experienced a myocardial infarction (Turkulin et al., 1977). Morgan et al. (1973) found that HR did not follow RPE under hypnotic suggestions of increased workloads, as $\dot{V}O_2$, $\dot{V}CO_2$, ventilation and RPE increased. In further studies, Allen and Pandolf (1977) concluded while breathing an enriched O_2 mixture and exercising, RPE declined significantly even though HR, venilation ($\dot{V}_E$) and respiration rate (RR) were not affected.

Several studies have been done concerning the effects of age and/or sex on perceived exertion and its relationship to HR (Bar-Or, 1977; Borg & Linderholm, 1967; Arstila et al., 1977; Hage, 1981; Henriksson et al., 1972). As a person gets older they perceive a given workload more difficult (Bar-Or, 1977). He also stated that children age 7-9 perceive effort higher than adolescents or adults do. Borg and Linderholm (1967) found a negative correlation between heart rate at a given RPE and age. Men ages 20-39 had a higher HR at RPE values of R_9, R_{13}, and R_{17} than men ages 50-79. Arstila et al. (1977) achieved similar results for both males and females. However, women perceived submaximal workloads more strenuous than males. This is in agreement with Hage (1981) who found some females had a HR 10-15 beats per minute higher than males at 50% $\dot{V}O_2$ max. These studies indicate that factors other than HR influence one's perception of effort.

Ventilation and RPE

Major controversy still exists concerning the relationship between perception of effort and ventilation ($\dot{V}_E$). Several studies (Edwards et al., 1972; Skinner et al., 1973; Morgan et al., 1973; Noble, Metz, Pandolf, & Cafarelli, 1973; Kamon et al., 1974; Morgan, Hirota, Weitz, & Balke, 1976; Salomon, Eulur, & Franzen, 1977; Horstman, Weiskoof, & Robinson, 1979) support the idea that $\dot{V}_E$ is a major cue in the perception of effort. Edwards et al. (1972) found significant correlation between RPE and $\dot{V}_E$ during continuous and intermittent work on a bicycle with the same power output. Skinner et al. (1973) found no difference in RPE-$\dot{V}_E$ relationships between lean and obese subjects when tested on a bicycle and a treadmill during different environmental temperatures providing ventilation measures were examined as relative to maximum values. Changes in RPE were explained by Morgan et al. (1973) and Morgan, Hirota, Weitz and Robinson (1976) due to changes in ventilation during hypnotic suggestions. Noble, Metz, Pandolf, and Cafarelli (1973) found $\dot{V}_E$ to be very important early in an exercise bout. Minute ventilation accounted for the most variance in the first 15 minutes of activity in a neutral and heated environment when cycling. Kamon et al. (1974) determined $\dot{V}_E$ and $\dot{V}O_2$ to correlate well with RPE even during exercise in a heated environment. Salomon, Eulur and Franzen (1977) found that sensory cues from ventilation were of a ratio scaling type, better understood by magnitude estimations. As ventilation increased, the magnitude of its cue to perceived exertion increased, giving it a major role in RPE. Ventilation and circulation were primary factors influencing activity at high altitudes in a study by Horstman, Weisdoff and Robinson (1979). A few studies (Pandolf et al., 1972; Robertson, 1982) have suggested that $\dot{V}_E$ becomes a factor at an intensity of higher than 50% VO_2 max. Pandolf et al. (1973) found that low intensities or workload changes of less than 200 Kpm/min. caused no change in $\dot{V}_E$ or RPE. Robertson (1982) concluded that respiratory mechanoreceptors provided important signals to effort sense when peak tidal volume was achieved. This was where RPE and $\dot{V}_E$ began to parallel. A study by Peterson and Welch (1977) found $\dot{V}_E$ and RPE to drop when a

50% O_2 mixture was inhaled by the subjects. But when an 80% O_2 mixture was given, $\dot{V}_E$ dropped with no relation to RPE signifying $\dot{V}_E$ to be only partially responsible for changes in RPE values.

Some studies (Horvath & Michael, 1970; Michael & Hackett, 1972; Michael & Eckhardt, 1972; Poulus, Docter, & Westra, 1974; Stamford & Noble, 1974; Cafarelli & Noble, 1976; Allen & Pandolf, 1977; Cafarelli, 1977; Wigertz, 1970; Wilson & Welch, 1975) dispute the importance of a significant relationship between $\dot{V}_E$ and RPE. Horvath and Michael (1970), when testing young women on a treadmill during gradually increasing workloads and during constant workloads until maximum, found trained women achieved a higher $\dot{V}O_2$ max with equal RPE values, yet ventilation differed significantly indicating it was not a major factor in RPE. Both Michael and Hacket (1972) and Michael and Eckhardt (1972) also found that $\dot{V}_E$ was not a significant factor in influencing the perception of effort under differing work conditions. Michael and Hackett (1972) showed bicycle work to be more stressful than treadmill exercise yet $\dot{V}_E$ did not reflect any difference. Michael and Eckhardt (1972) found that subjects tested on a treadmill could find equal power outputs at 0% and 10% grade in relation to $\dot{V}O_2$ and HR, however $\dot{V}_E$ differed significantly, therefore was not considered to be a major cue in perception of effort. Poulus, Docter and Westra (1974), testing ten males on a bicycle while trying to control pH balance by infusion of $NaHCO_3$ 8%, found a reduction in ventilation while RPE, HR and $\dot{V}O_2$ remained unchanged. They then also concluded that $\dot{V}_E$ was not a significant factor in perceived exertion. Stamford and Noble (1974) questioned the importance of $\dot{V}_E$ and other metabolic factors upon discovering RPE was significantly higher when bicycle work was done at slower pedal speeds with equal power outputs. Cafarelli (1977) achieved similar results when he found no significant difference between $\dot{V}_E$ at different pedal rpms while RPE was higher at lower rpms. Cafarelli and Noble (1976) attempted to determine the exact effect $\dot{V}_E$ had on RPE by increasing $\dot{V}_E$ during running and cycling with inspired CO_2. This procedure caused increased ventilation without altering HR or $\dot{V}O_2$ consumption. RPE did not follow changes in $\dot{V}_E$ but remained the same. They concluded that $\dot{V}_E$ was not a primary cue for perceived exertion, however they did note that levels of CO_2 and ventilation at high levels becomes a more important cue in RPE. This note is similar to the findings of Pandolf et al. (1972) and Robertson (1982) previously mentioned. In 1977, Allen and Pandolf concluded that $\dot{V}_E$ was not a factor in the perception of effort. They tested twelve subjects having them breathe extra rich O_2 mixtures during submaximal work and found that RPE was reduced and $\dot{V}_E$, RR, and HR was not affected. Wilson and Welch (1975) found $\dot{V}_E$ to decrease at any point when breathing hypertoxic mixtures. Wigertz (1970) added that controls of cardiac output and ventilation are different from those directly affecting perceived exertion. Readjustments in ventilation lag HR by approximately 30 seconds; therefore perception of load related to ventilation is not an accurate one.

<u>Respiration Rate and RPE</u>

In several studies (Edwards et al., 1972; Pandolf et al., 1972; Noble et al., 1973; Poulus et al., 1974; Robertson, Gillespie, McCarthy,

& Rose, 1979) respiration frequency (RF) was shown to be a significant factor affecting RPE during exercise. Others (Lollgen et al., 1977; Allen & Pandolf, 1977; Cafarelli, Cain, & Stevens, 1977) have found RF to be less of a factor influencing perceived exertion.

Edwards et al. (1972) found that RPE ratings correlated significantly to RF during continuous work (r = .66). Pandolf et al. (1972) studied relationships between RPE and RF after finding that heat stress increased HR without affecting RPE. In the absence of a strong HR, RPE relationship, RF had the strongest correlation (r = .60) with RPE during the last half of a 30-minute exercise routine. Other measures, $\dot{V}_E$, $\dot{V}O_2$ and HR had no dominant force on the sensation of effort. Their conclusion was that RF did have a significant effect on perceived exertion during exercise under heat stress. Agreements to this were made by Noble et al. (1973) when they also found RF contributed a major cue to RPE during the last 30 minutes of a 45-minute exercise bout. Poulus et al. (1974) determined that infusions of 8% $NaHCO_3$ had no effect on RPE, RF, HR, and $\dot{V}O_2$ signifying that along with HR and $\dot{V}O_2$, RF was a factor directly influencing RPE. A more recent study by Robertson, Gillespie, McCarthy and Rose (1979) focused on the relationship between local and central physiological responses to work. RPE was found to be higher in work done on a bicycle at 40 rpms than it was at 60 rpms or 80 rpms. HR, $\dot{V}O_2$, $\dot{V}_E$ and RF were all higher at the lower rpms indicating each of these parameters being significant factors that influence perceived exertion.

In opposition to the fact that RF was found to be a significant factor influencing RPE, Lollgen et al. (1977) found RF was less at low pedal speed and higher at increased pedal speeds while RPE was the opposite. RPE was found to be higher at lower rpms even though power outputs were equal at all work levels. Allen and Pandolf (1977) did not support RF as a significant factor in RPE. RF, $\dot{V}_E$, and HR were not affected by breathing hypertoxic mixtures; however RPE declined. Cafarelli, Cain and Stevens (1977) concluded that central factors such as $\dot{V}_E$, RF, and HR were only small contributors in sensation of work effort, especially when smaller amounts of muscle mass were used.

Central and Local Factors and RPE

The general theme of many studies has been focused on ascertaining what factors were directly responsible for a subject's perception of effort. Such studies have supported that RPE was related to the metabolic cost of work (Borg, 1962; Borg & Linderholm, 1967; Astrand, 1977; Cafarelli, 1978). However, others (Ekblom & Goldbarg, 1971; Pandolf et al., 1972; Noble et al., 1973; Pandolf & Noble, 1973; Stamford & Noble, 1974; Teghtsoonian, Teghtsoonian, & Karlsson, 1977; Lollgen, Graham, & Sjogaard, 1980; Pandolf, 1982; Young, Cymerman, & Pandolf, 1982) have found that RPE does not always reflect the metabolic cost of work. Ekblom and Goldbarg (1971) found that HR didn't follow the linear association to RPE when manipulated by beta blocking drugs. Pandolf et al. (1972) altering HR with heat stress found similar results. Stamford and Noble (1974) concluded that metabolic cost of work indicated by HR, $\dot{V}O_2$, $\dot{V}_E$, O_2 debt and La concentration did not correlate with work on a bicycle at different rpms.

Based on these findings it became apparent that some other cues were important in determining subjective feelings of effort.

Perceived exertion was identified as a complex process that involves many factors of which two appear to dominate: (1) central factors that include the metabolic parameters of work, and (2) local factors which are influenced by the local sensations of pain and stiffness in the working muscles and limbs (Ekblom & Goldbarg, 1971). Local factors were seen to vary in their importance to RPE depending on the situation. Work with small amounts of muscle mass involved local factors more in RPE than did working with large amounts of muscle mass (Ekblom & Goldbarg, 1971; Gamberale, 1972; Sargeant & Davies, 1973; Cafarelli et al., 1977). Cafarelli and Noble (1976) concluded that local factors dominated perception up to 70% of maximum capacity whereby central factors took over the dominant cue for RPE. This was similar to results achieved by Cafarelli et al. (1977). They suggested local sensations from the working limbs accounted for the majority of the feelings of exertion in static hand gripping tasks and dynamic tasks of cycling and arm cranking.

Several studies (Gamberale, 1972; Pandolf & Noble, 1972; Noble et al., 1973; Stamford & Noble, 1974; Robertson, McCarthy, & Gillespie, 1976; Pandolf, 1978; Weiser & Stamper, 1977; Robertson, Gillespie, McCarthy, & Rose, 1979; Robertson, 1982) provided evidence to support the local factor concept. Gamberale (1972) required subjects to rate overall RPE and local RPE. Local ratings were higher for leg and arm work than overall ratings for the same activities. Pandolf and Noble (1973) and Robertson et al. (1976) found negative relationships between RPE and pedal speed during work on a bicycle ergometer. They found the local stress on the limbs directly influenced the overall RPE.

Nearly identical results were attained by Stamford and Noble (1974). They found that RPE was highest at 40 rpm when compared to 60 rpm and 80 rpm during continuous and intermittent work due to localized leg fatigue.

Noble et al. (1973) found walking at a speed of 4.32 mph was perceived more difficult than running even though the metabolic cost of walking was less than running. It was felt the inefficiency of walking at high speed caused the undue localized stress on the legs. Weiser and Stamper (1977) found leg fatigue to be the major cause of RPE changes during prolonged strenuous bicycle riding. Local factors of muscle strain and blood La were used by Pandolf (1978) to identify their contribution to RPE during physical work. He concluded that when muscle strain is high, local factors are the dominant cues in perception of effort.

Robertson (1982) identified local cues as being the dominant factors influencing RPE regardless of the intensity of the physical work. He further concluded that central factors only become significant when effort is above 70% of maximum capacity.

More recent research has focused on the central cues of perceived exertion (Borg, Karlsson, & Eklund, 1977; Pandolf, Burse, & Goldman, 1975; Robertson, Gillespie, McCarthy, & Rose, 1979; Lollgen, Graham, & Sjogaard, 1982; Pandolf, 1982; Young, Cymerman, & Pandolf, 1982). Borg et al. (1977) found that HR was used effectively to control work and RPE at submaximal workload where HR was between 120-170 beats per minute. Pandolf et al. (1975) found that central factors dominated perceived exertion when doing treadmill work. Robertson et al. (1979) concluded that central cues were critical in overall perception of effort at various pedal speeds of equal power outputs. HR, $\dot{V}O_2$, $\dot{V}_E$ and RF were all higher at the lower rpms. These increased values paralleled a rise in RPE values indicating the central cues as the dominant factors in ratings of RPE. Young et al. (1982) concluded that central factors were dominant when cycling at high altitudes but local factors were stronger when working at sea level. The difference between high and low altitude was explained by the increased lactic acid production at sea level and it's low level at high altitudes.

This combination between central and local factors was also examined by Lollgen et al. (1980) and Pandolf (1982). Pandolf designed a model to help isolate different cues and their importance in RPE and he concluded that most local factors are too hard to quantify so the data are only correlational and do not imply causality. Lollgen et al. (1980) suggested that central or local cues independently cannot account for a significant change in perception of effort. In cycling at different speeds with equal power outputs, changes in central factors did not elicit a change in RPE. Likewise when local factors increased no increase in RPE was observed. Only when both types of cues were combined did the overall RPE correspond to actual work effort.

<u>Women and RPE</u>

Very few studies in perceived exertion have used women subjects. Only four of these studies have yielded comparative information concerning the possible differences in RPE between males and females

(Borg & Linderholm, 1970; Henriksson et al., 1972; Arstila et al., 1977; Noble et al., 1981).

Borg and Linderholm in 1970 found that women had slightly higher HRs for a specific RPE value than men. However, this was only noted for a rating of 9 in the 20-24 year old age group. The researchers further stated that there were no observable differences between sexes when ratios of physical working capacity as determined from workload when an RPE of 13 and 17 were compared.

Arstila et al. (1977) compared HR-RPE relationships in men and women. When women were compared alone HR-RPE relationships were linear. However, when combined with men, women perceived work slightly higher for a given HR as compared to men. These findings were in contrast to Borg and Linderholm (1970) that indicated women had a lower RPE at a given HR than men.

In a study by Noble et al. (1981) in which women and men were compared, they found that women had higher RPE values related to absolute levels of O_2 consumption than men. However, when the same RPE values were compared to relative percent values of $\dot{V}O_2$ max, there was no significant difference between men and women.

In addition to the results of Noble et al. (1981), Borg (1977) concluded as an overview of past research in perceived exertion that women will choose a higher RPE for a given workload than men, but if that workload is expressed relative to maximum capacity, no differences between men and women are found.

Chemical Influences on RPE

Five studies have dealt with chemical influences on the perception of effort (Frankenhaeuser, Post, Nordheden, & Sjoeberg, 1969; Ekblom & Goldbarg, 1971; Poulus et al., 1974; Howley, 1976; Squires et al., 1982). Frankenhaeuser et al. (1969) and Howley (1976) looked at catecholamine levels and outputs during exercise to determine if these internal chemical substances directly affect RPE. Both studies showed increases in catecholamine levels as workloads increased but not significantly to identify them as cues for perceived exertion.

Poulus et al. (1974) attempted to influence RPE by blood infusions of an 8% solution of $NaHCO_3$. They found it had no effect on RPE, HR, RF, $\dot{V}O_2$ or feelings of fatigue. The only recorded change was a reduction in $\dot{V}_E\ CO_2$.

In two separate studies, Ekblom and Goldbarg (1971) and Squires et al. (1982) attained similar results in relation to beta blocking agents administered to post MI patients. They both concluded that RPE was not affected by the reduced HR during exercise caused by the beta blocking drugs, and that breathing rate and muscular sensations were the primary cues for perceiving effort.

Summary

Perceived exertion has been defined as "subjective feelings of work" by Borg (1978, p. 215). Numerous physiological and neurological responses have been proposed as primary factors for input into the perception of effort. Although some responses are able to be directly perceived, the way in which sensory inputs are handled and combined by the individual to determine perceived exertion remains unclear (Mihevic, 1981). In an earlier paper, Mihevic (1979) attends to not only RPE, but magnitude estimation as well, to assess different parts of perceived exertion.

Several other studies have identified motivation as a key factor in perception of effort (Kinsman, Weiser, & Stamper, 1973; Kinsman & Weiser, 1976; Pandolf, 1977; Horstman, Morgan, Cymerman, & Stokes, 1979). Kinsman et al. (1973) and Kinsman and Weiser (1976) found that task aversion and motivation were two critical parts of perceiving effort. Sixty-four males rode bicycle ergometers at submax until self imposed exhaustion. Over half the group had higher RPE values than expected at lower workloads, indicating some motivational interference with the perception of effort.

Bartley (1970) proposed a different identification process for sensory feedback. He concluded that there are only two major sources of information for the perception of effort. They are the homeostatic receptors and the comfort receptors, each having equal responsibility to the overall RPE. Sargeant and Davies (1977) used this concept and found that subjects with leg injuries could use RPE as an assessment of exercise by temporarily redistributing the importance of each perceptual cue. Although this may have appeared novel, it only reaffirms Borg's initial experiments (Borg & Dalstrom, 1960; cited in Borg, 1960; Borg, 1962) with ratio scaling methods. This method worked well but no comparisons could be made between individuals.

Borg (1973) reported that the revision of the old 21-point scale used for individual comparison to a 15-point scale improved the correlation to the subject's actual HR. Many studies that followed Borg's original studies reported that RPE correlated well with the metabolic cost factors such as HR (Borg, 1962; Skinner et al., 1972; Edwards et al., 1972) and respiratory factors, i.e. $\dot{V}_E$ and RF (Ekblom & Goldbarg, 1971; Edwards et al., 1972; Pandolf et al., 1972; Noble et al., 1973). In some other cases, factors associated with pain and stress provided support for the dominance of "local factors" (Gamberale, 1972; Stamford & Noble, 1974; Pandolf, 1978; Robertson et al., 1979; Robertson, 1982).

Comparisons between men and women and their ability to perceive work has been studied. Although some studies (Borg & Linderholm, 1970; Henriksson et al., 1972; Arstila et al., 1977; Noble et al., 1981) have reported differences in RPE between men and women, the data are limited and inconclusive.

The perceived exertion literature in general indicates that perceptual responses to work must be evaluated in terms of exercise intensity, exercise duration, steady state exercise versus progressive exercise, and exercise modality. Unless these physiological responses are not consciously monitored, it is unlikely they will act as a dominant cue for the perception of effort.

CHAPTER III

METHODS

The purpose of this study was to determine if cardiovascular condition of college age women and the level of work being done affects their ability to subjectively perceive efforts of work. It was hypothesized that cardiovascularly conditioned women could subjectively perceive effort better than cardiovascularly unconditioned women and that accuracy of perceived exertion would increase at higher work loads.

Design

This investigation was conducted using a quasi-factorial design. The independent variables were the cardiovascular condition of the subjects and the workloads the subjects selected to attain an assigned RPE value. The twenty subjects were divided into two groups according to their cardiovascular condition determined by their O_2 consumption during trial 1 (T_1). Cardiovascular conditioned were those who had a $\dot{V}O_2$ of 45 ml/Kg·min^{-1} or more and a history of training and cardiovascularly unconditioned were those who had a $\dot{V}O_2$ of 40 ml/Kg·min^{-1} or less and no history of training. In trial 2 (T_2), the assigned RPE values were equal to 20%, 60% and 85% of each subject's max HR difference. The dependent variables in this study were heart rate (HR) and RPE, measured at those three assigned values.

Subjects

Twenty college age females at the University of Northern Iowa volunteered as subjects for this study. No subject was under the care of a physician, took medication, or had any condition which might have influenced the response to exercise during the study. All subjects were informed of the task requirements and the risks involved, and signed an appropriate consent form (see Appendix A).

Procedure

Measures of resting HR, maximal HR, $\dot{V}O_2$, and perceived exertion (RPE) were determined during T_1 for each subject. The subjects were tested in the human motor performance laboratory at the University of Northern Iowa. The purposes and procedures of each test were explained to each individual prior to their commitment as volunteers. Verbal and written instructions were given to each subject concerning the use of the RPE scale and verbal explanations of the other test were presented prior to each activity. Any questions the subjects had were answered by the researcher to the best of his ability.

Instructions for attaining RPE ratings were read by each subject and then reread aloud by the researcher to insure a correct response (see Appendix B). The electronically braked Pedal Mode Ergometer was adjusted for proper seat and handle bar height. Two silver/silver chloride electrodes were placed on the subject in a CM_5 lead position. The subjects were to rest five minutes lying on their back. They were requested not to talk or move. At the end of the fifth minute, a ten-second ECG determined resting HR. During the five-minute resting period, the researcher calibrated the CO_2 and O_2 analyzers of the Beckman Metabolic Measurement Cart. The subjects then mounted the ergometer and a nose plug and headgear were adjusted to fit comfortably. The gas collection hose was attached and positioned to prevent any undue discomfort to the subjects. Each subject began to pedal at 50-60 rpms at a workload of 50 watts. At the end of a three-minute interval the workload was increased by 50 watts and continued to increase by that same amount every three minutes until max heart rate was achieved. During the last thirty seconds of each workload, RPE was recorded and a ten-second ECG was run to determine HR. The test was terminated by achieving max HR measured by a 10-second ECG or by failure of the subject to maintain 50-60 rpm at a given workload.

The subjects were asked to return for a second time, two to five days after the initial test (T_1). The subjects were instructed on how to adjust the workload of the Pedal Mode Ergometer without altering rpms. By turning the knob clockwise they could increase the resistance and counter clockwise decrease the resistance. The tachometer in front of them was covered so as not to disclose their pedal speed. Exercise trials were then administered at selected work intensities (T_2). These intensities were the RPE values representing 20%, 60% and 85% of max HR differences for each subject. These RPE values were presented in random order. The subjects pedaled five minutes and were allowed to adjust the workloads to generate the desired RPE sensation. Four and one-half minutes were allowed for the adjustments at an assigned RPE. Times were read aloud at 1, 2, 3, 4 and 4.5 minutes during the trials so final adjustments could be made. At the end of the five-minute period, a ten-second ECG and the final workloads were recorded. This was done for each of the three trials (T_2). A sufficient amount of time was allowed to enable each subject to return to a "rested state" before attempting the next trial. A "rested state" was determined by heart rate being less than 20% of max HR difference as computed by the Karvonan's principle.

Resting HR. Prior to exercise, each subject was instructed to relax for five minutes on their back while a modified CM_5 lead ECG (Fukuda Century Super Cardiart, Tokyo) was recorded during the last fifteen seconds of the fifth minute.

Oxygen Consumption. The subjects were requested to pedal a bicycle ergometer for three-minute intervals at a rate of 50 rpm. Each individual started at 50 watts and increased 50 watts every three minutes until they could no longer maintain the 40 rps indicated by the tachometer on the bicycle ergometer. Data including $\dot{V}_E$ and $\dot{V}O_2$ were collected by the Beckman Metabolic Measurement Cart after the fifth minute of the test.

Maximal HR. During the O_2 consumption test, a six-second ECG (Fukuda Century Super Cardiart, Tokyo) using a CM_5 lead was taken in the final fifteen seconds of the three-minute intervals at each successive workload. Maximal HR was determined to be the highest HR attained when an increase in workload did not elicit an increase in HR.

Ratings of Perceived Exertion (RPE). Instructions for the Borg RPE scale were read by each subject, then reread by the researcher to insure a correct response (see Appendix B). The scale is a bi-polar scale for eliciting RPE using numbers from 6 to 20, with each odd number accompanied by a phrase ranging from "very very light" at 7 to "very very hard" at 19 (Figure 1). Overall RPEs for trial 1 were requested by the statement "rate your exertion" (Smutok, 1980, p. 510). At this time the subjects were to point to one number on a 2' by 3' chart of the Borg RPE scale held in front of them by the researcher that related to their feeling of effort during the last 30 seconds of each three-minute interval.

Assigned RPE values. To determine the correct RPE rating relating to 20%, 60% and 85% of max HR difference, the resting HR was subtracted from the max HR to get the difference. That difference multiplied by the percent factor for each trial added to the subject's resting HR was assigned a specific RPE value correlating with the Borg 15-point scale.

Analysis of Data

The values measured were RPE at selected workloads and HR at three different assigned RPE values. To find out if the cardiovascular condition and training of college age women affect their ability to accurately predict HR, differences were determined between RPE and HR. To test these differences, the RPE values were first multiplied by 10 as indicated by Borg (1973). Once the RPE values were multiplied by 10, correlated T-tests were used to compare the multiplied RPE and HR for trial 1 (T_1) and trial 2 (T_2). A repeated measure analysis of variance was used to compare RPE and HR between groups. Correlation coefficients were determined to identify the strength or magnitude of the relationship between RPE and HR on the bicycle ergometer and motor driven treadmill for T_2. Slope intercept formulas were also determined for regression lines to help visualize the relationship between RPE and HR for T_1 and T_2. The regression lines of each group were used so that RPE could be compared at different workloads in percentages of maximum HR.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine if the cardiovascular condition of college age women affects their ability to subjectively perceive efforts of work on a bicycle ergometer and a motor driven treadmill at submaximal workloads under normal conditions. In trial 1 (T_1) RPE values were elicited for progressively increasing workloads until a max HR value was attained. Trial 2 (T_2) consisted of three submaximal workloads equaling 20%, 60% and 85% of each subject's HR reserve (HRR) calculated using the Karvonan principle. It was hypothesized that cardiovascularly conditioned women of college age with a $\dot{V}O_2$ of 45 ml/Kg·min^{-1} or more and a history of training could subjectively perceive effort better than women of college age with a $\dot{V}O_2$ of 40 ml/Kg·min^{-1} or less and no history of training. It was also hypothesized that the accuracy of perceived exertion ratings would increase at higher workloads with all subjects.

To test these hypotheses, relationships were determined between RPE and HR for selected workloads during T_1 and T_2 by correlated T-tests. A repeated measures analysis of variance was used to compare RPE and HR within groups. Correlation coefficients were determined to identify the strength or magnitude of the relationship between RPE and HR on the bicycle ergometer and motor driven treadmill for T_2. Slope intercept formulas were also determined for regression lines to help visualize the relationship between RPE and HR for T_1 and T_2. The regression lines of each group were used so that RPE could be compared at different workloads in percentages of maximum HR.

Subject Characteristics

Of the subjects involved in the study, nine were classified conditioned and eleven unconditioned, as explained by the descriptive characteristics in Chapter III. Table 1 contains the range, mean values and standard deviations of age, weight, resting HR, max HR, $\dot{V}O_2$, and max RPE for both groups attained in T_1. Resting HRs for the conditioned and unconditioned groups ranged from 48-80 beats per minute and 60-90 beats per minute respectively. The conditioned group had a max HR range of 175-190 beats per minute and the unconditioned group was slightly higher with a range starting at 180 beats per minute up to 200 beats per minute. A correlated T-test (Weinberg, Schumaker, & Oltman, 1981, pp. 99-101) was used to determine if there was a significant difference between max HRs. A T-value of 3.32 was found to be significant at the .05 level between the mean max HR values of 181.67 beats per minute for the conditioned group and 190.45 beats per minute for the unconditioned group. These mean rates are in agreement with previous studies relating conditioning to max HR values. As stroke volume increased through conditioning, max HR decreased (Doctor & Sharkey, 1971). Although the max HR ranges were higher for the unconditioned group, the max RPE range of 17-20 was identical for both groups. As explained by Ekblom and Goldbarg (1971), when relative max HR and RPE are compared, no significant differences are expected. In the conditioned group a mean $\dot{V}O_2$ of 47.0 ± 1.44 ml/Kg·min^{-1} was

Table 1

General characteristics of conditioned and unconditioned subjects.

General Characteristics	Conditioned N=9			Unconditioned N=11		
	Range	Mean	S.D.	Range	Mean	S.D.
Age (yr.)	20-30	25.77	3.46	19-26	21.20	2.14
Weight (lbs.)	115-140	127.20	11.23	118-148	137.90	9.10
Rest HR (bts/min)	48-80	61.56	9.51	60-90	73.91	9.62
Max HR (bts/min)	175-190	181.67	5.60	180-200	190.45	6.11
$\dot{V}O_2$ (ml/Kg·min^{-1})	45.0-48.9	47.00	1.44	27.6-36.3	32.78	3.08
Max RPE	17-20	18.78	.97	17-20	18.45	1.04

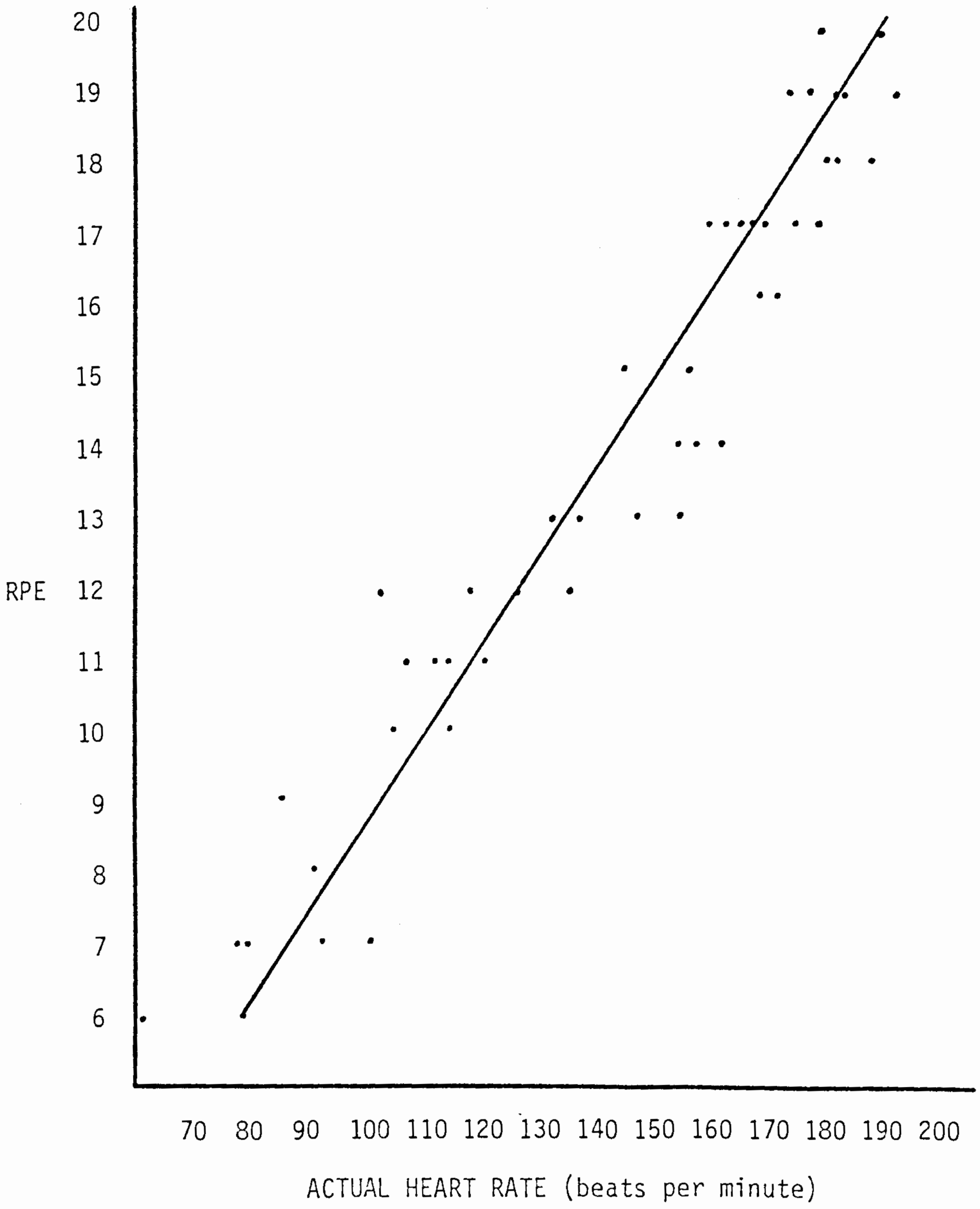

Figure 3. Scattergram with line of best fit for conditioned subjects during T_1.

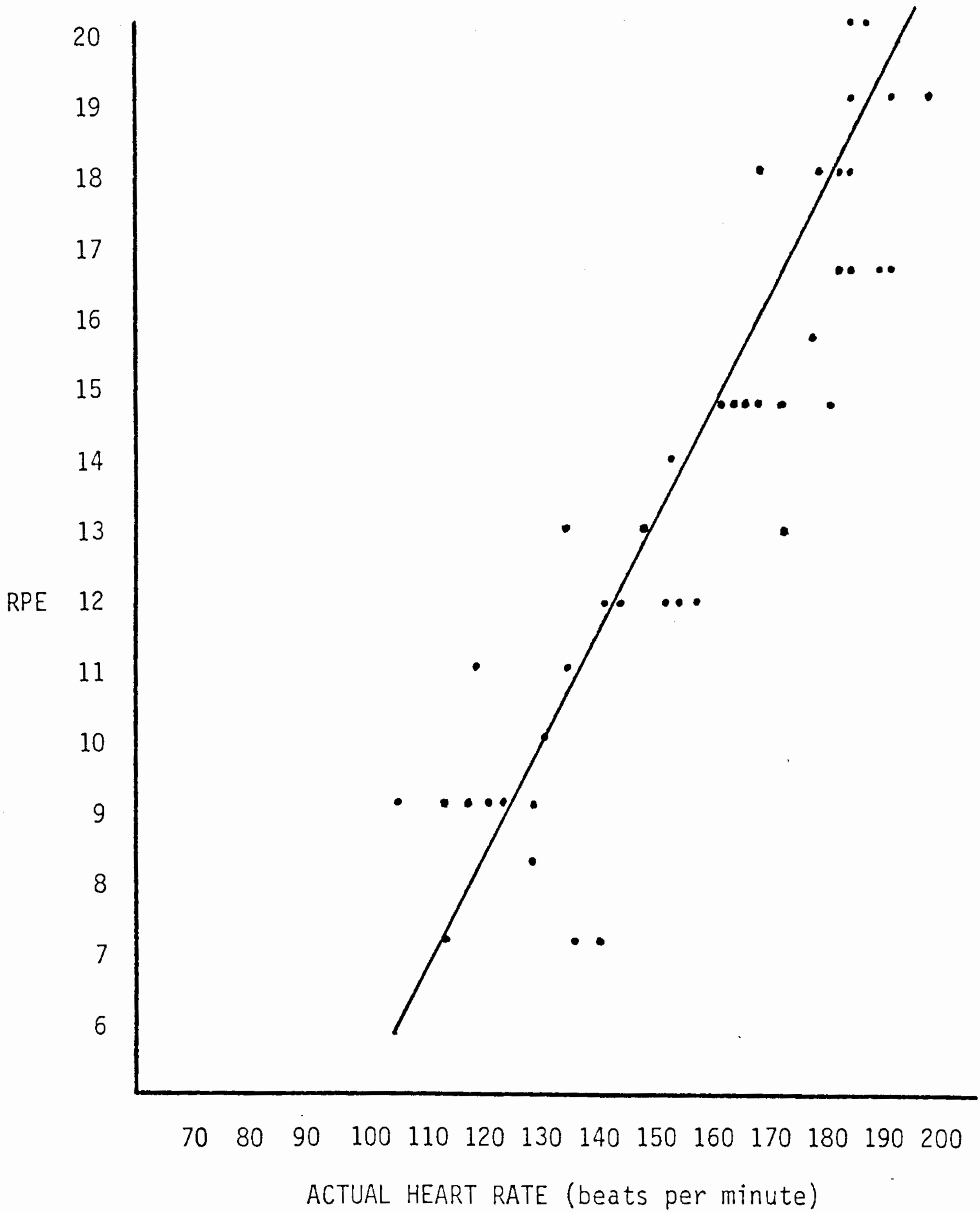

Figure 4. Scattergram with line of best fit for unconditioned subjects during T_1.

Table 2

Correlated T-tests for trial T_1 between RPE and HR for specified workloads.

Workload in watts	Group	N	HR Mean	HR S.D.	RPE Mean	RPE S.D.	T Value	2-Tail Probability
50	C	8	89.25	17.57	7.88	1.72	2.56	.038*
	U	11	123.64	10.12	8.55	1.21	6.89	.000*
100	C	9	117.11	14.46	10.89	1.36	2.25	.052
	U	11	150.91	10.00	12.36	1.57	5.54	.000*
150	C	9	142.44	14.48	13.67	1.58	1.59	.150
	U	11	177.27	9.14	15.82	2.36	3.09	.012*
175	C	1	-	-	-	-	-	-
	U	4	186.25	4.79	18.25	1.71	0.40	.718
200	C	9	165.44	13.24	16.44	1.67	0.25	.811
	U	6	191.67	6.83	17.17	2.23	2.98	.031*
225	C	5	180.00	12.25	18.40	1.14	-1.63	.178
	U	1	-	-	-	-	-	-
250	C	5	179.00	4.18	18.60	0.89	-2.06	.108
	U	-	-	-	-	-	-	-

*$p < .05$

C = conditioned subjects

U = unconditioned subjects

recorded compared to a mean $\dot{V}O_2$ of 32.78 ± 3.08 ml/Kg·min^{-1}. These values are representative of the difference between the cardiovascularly conditioned and unconditioned subjects as defined by this study.

Relationship between RPE and HR for T_1

RPEs were recorded at the end of each three-minute workload starting at 50 watts and increasing 25 watts or 50 watts until the increase in workload did not elicit an increase in HR. During each of these workloads, the subjects were asked to indicate their level of effort using the Borg scale (Figure 2). Figure 3 illustrates the ability of the conditioned group to predict their HR at each progressively increasing workload. The range in RPE predictions was from 6 to 20 and their actual HR ranged from 58-195 beats per minute. Figure 4 shows the data for the unconditioned group with an RPE range from 7 to 20 and actual HRs ranging from 100-200 beats per minute.

RPE multiplied by 10 as described by Borg (1973) was used to determine the predicted HR for each workload. Correlated T-tests to detect any mean differences between actual HR and predicted HR using the RPE value were done for both groups at all workloads. As the data shown in Table 2 indicates, the differences between predicted HR and actual HR were significant for workloads of 50, 100, 150 and 200 watts for the unconditioned group. The conditioned group, however, showed a significant difference between predicted HR and actual HR for only the 50 watt workload. The unconditioned group did not show a significant difference at the 175 watt workload. However, the four subjects that worked at that level were near max HR as well as max RPE. In comparing the mean HRs between groups at each workload, one can note a much greater difference in HRs than can be noted between RPE values used to determine actual HR for the identical workloads. Dale and Anderson (1978) also showed that subjects with a higher stroke volume and lower HR due to training perceived HR changes better than subjects with lower stroke volumes and no training. The effects of training on local factors may play a more important role than central factor changes (Morgan, 1983). He concluded that conditioned individuals pay closer attention to local factors such as muscle fatigue, pain, and breathing rhythm, thus enhancing their own ability to perceive HR and effort. Based on their findings, it is apparent that perceived exertion is a complex process involving both central factors that include metabolic parameters of work and local factors influenced by local sensations of pain and stiffness in the working muscles (Ekblom & Goldbarg, 1971).

Regression lines and regression equations were determined and presented in Figure 5 comparing the conditioned group with the unconditioned group for HR and RPE. It is apparent from Figure 5 that the unconditioned group had much higher HRs at lower RPE ratings than the conditioned group.

Relationship Between RPE and HR for T_2

Correlated T-tests for the three assigned workloads for both groups in T_2 are presented in Table 3. In an effort to determine if there was a difference in HRs at submaximal workloads, not only between the two groups but between the two modes of exercise, RPE values

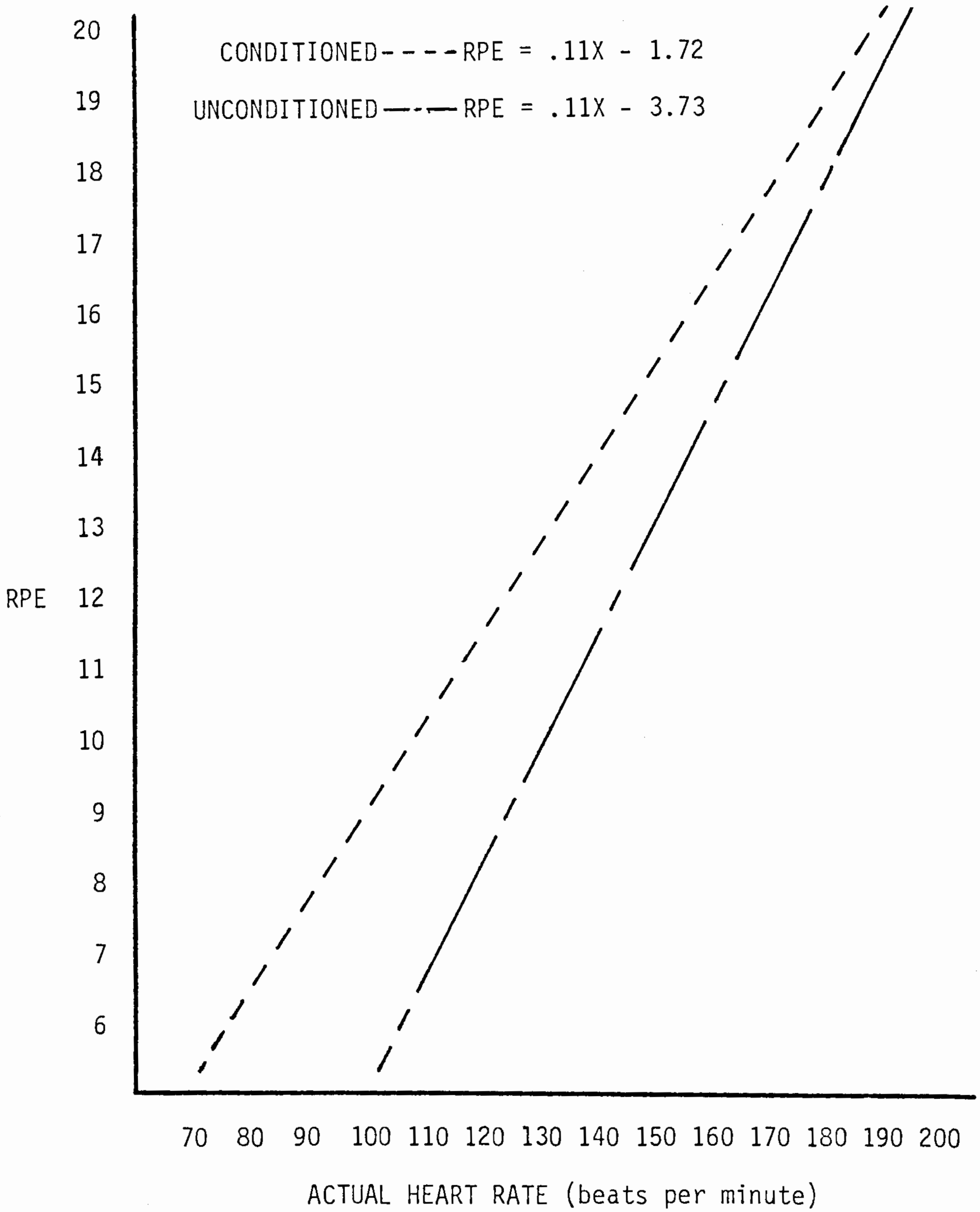

Figure 5. Regression lines and regression equations for the relationship between actual heart rate and RPE for T_1.

Table 3

Correlated T-tests for trial T_2 between RPE and HR for specified workloads.

Workload	Group	N	HR Mean	HR S.D.	RPE Mean	RPE S.D.	T Value	2-Tail Probability
20%B	C	9	98.00	11.84	8.56	.88	3.92	.004*
	U	11	136.45	20.08	9.55	.82	7.42	.000*
20%T	C	9	99.00	14.25	8.56	.88	4.23	.003*
	U	11	130.55	14.33	9.55	.82	7.09	.000*
60%B	C	9	135.44	9.98	13.22	.67	1.00	.347
	U	11	163.82	16.17	14.27	.47	5.00	.001*
60%T	C	9	138.33	17.38	13.22	.67	1.18	.273
	U	11	157.91	23.87	14.27	.47	2.28	.046*
85%B	C	9	156.56	16.40	16.22	.67	-1.46	.183
	U	11	177.27	10.82	17.09	.70	2.22	.051
85%T	C	9	158.22	19.96	16.22	.67	-.64	.537
	U	11	174.73	17.05	17.09	.70	.84	.423

*$p < .05$

C = conditioned subjects   U = unconditioned subjects

B = bicycle   T = treadmill

equaling 20%, 60% and 85% HRR were administered to each subject for the bicycle ergometer and the motor driven treadmill. In comparing the two groups at the 20% level for both modes of exercise, neither group could accurately predict their actual HR. Previous studies have shown that perception of effort is not accurate until a level of at least 45% HRR is achieved. Simon, Young, Gutin, Blood and Case (1983) determined that local factors are the greatest sensory cues for perceiving effort for 45-85% HRR. At low levels, Robertson (1982) identified local cues as being the dominant force influencing RPE. He further concluded that central factors do not become significant until a level of 70% HRR or more is reached. Morgan (1983) stated that conditioned individuals are more aware of these local factors, making them better perceivers of effort than unconditioned individuals. Although both groups showed a significant difference between RPE and HR for the 20% level, only the unconditioned group showed a significant difference between RPE and HR at the 60% workload. The unconditioned group's mean HR for an RPE of 14.27 was 163.82 beats per minute and 157.91 beats per minute for the bicycle ergometer and treadmill respectively. The conditioned group had a mean HR of 135.44 beats per minute on the bicycle and 138.33 beats per minute on the treadmill for an RPE of 13.22. Pollock (1983) presented Borg's 15-point scale (Borg, 1973) as a valid predictor of HR when levels of work ranged from 60% HRR to 85% HRR. At the 85% level, both groups were capable of predicting their actual HRs. Cafarelli and Noble (1976) and Cafarelli et al. (1977) both suggested that local and central cues are very strong at levels above 70% of max HR values. Turkulin et al. (1977) have shown that under normal exercising conditions using normal, healthy subjects, HR correlated significantly with RPE.

These differences between RPE and HR for the treadmill (Figure 6) and Bicycle ergometer (Figure 7) are shown with Borg's predicted line (Borg, 1973) with the mean HR values reported for the three assigned RPE values. From the original data points, regression lines and regression equations were determined for both groups and both modes of exercise. Figure 8 shows the results for the treadmill at the 20% level and Figure 9 shows the results for the bicycle ergometer at the 20% level. A comparison of slopes between groups (Kleinbaum & Kupper, 1978, p. 99) was made and T-values of 41.19 $p < .05$ for the bicycle and 88.35 $p < .05$ for the treadmill were recorded. The conditioned group at the 20% level showed a greater sensitivity to actual HR changes with RPE ranges of 7 to 13.6 for the treadmill and an RPE range of 7.5 to 15.1 for the bicycle ergometer. The unconditioned group would not perceive a change in actual HR on the treadmill and report an RPE of 9.42 irrespective of any HR changes. On the bicycle, however, the same group would detect a change in effort with RPE ranging from 8.3 to 10.6 increasing in intensity as HR increased. These findings are similar to the study by Ekblom and Goldbarg (1971) in which HR was found to be higher at a given RPE value on the bicycle ergometer as compared to the treadmill at the same RPE value.

Figure 10 shows the regression lines and regression equations for both groups on the treadmill for the 60% level. T-values for the com-

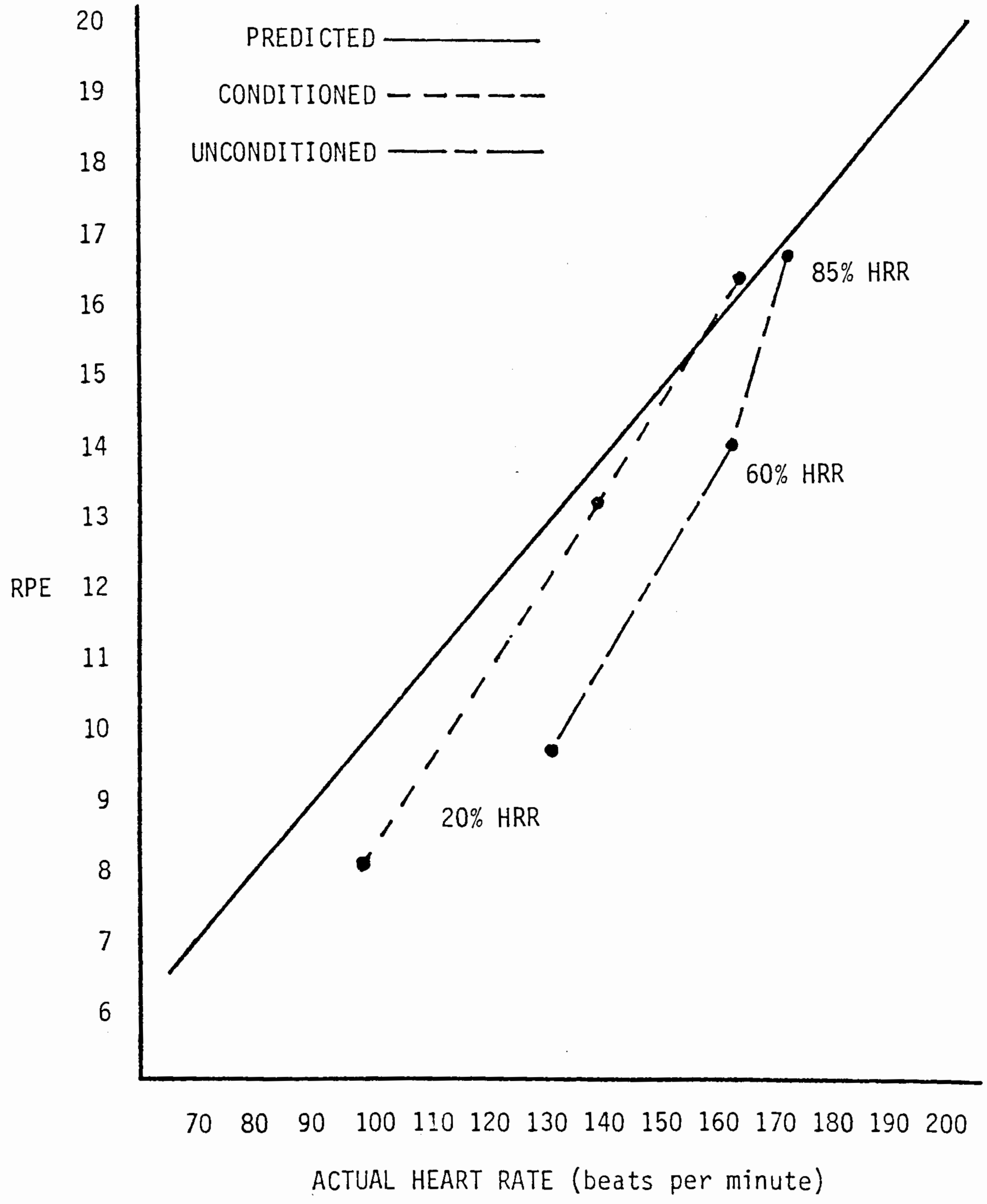

Figure 6. Relationship between HR and RPE for T_2 on the motor driven treadmill at 20%, 60%, and 85% of MAX HR.

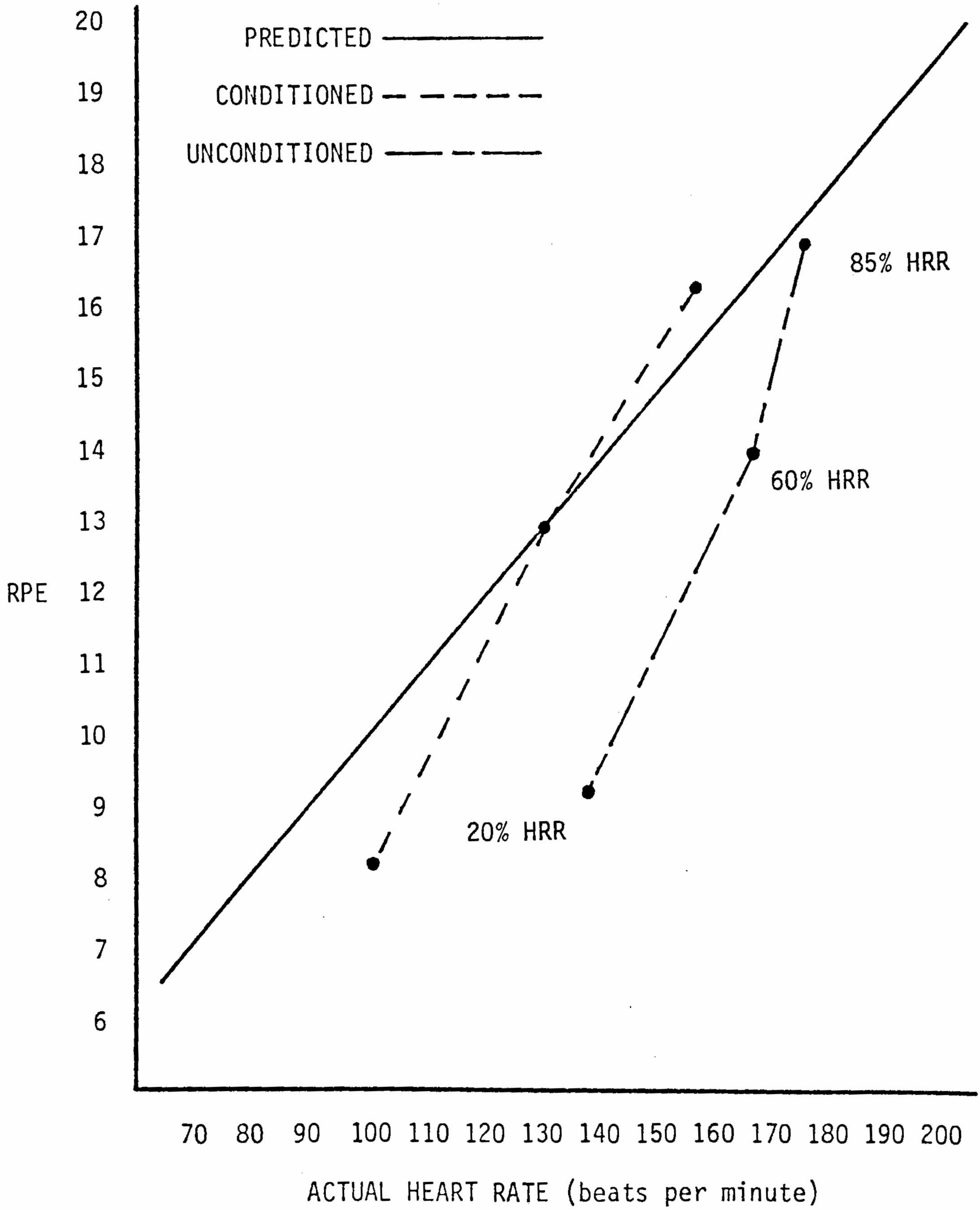

Figure 7. Relationship between HR and RPE for T_2 on the bicycle ergometer at 20%, 60%, and 85% of MAX HR.

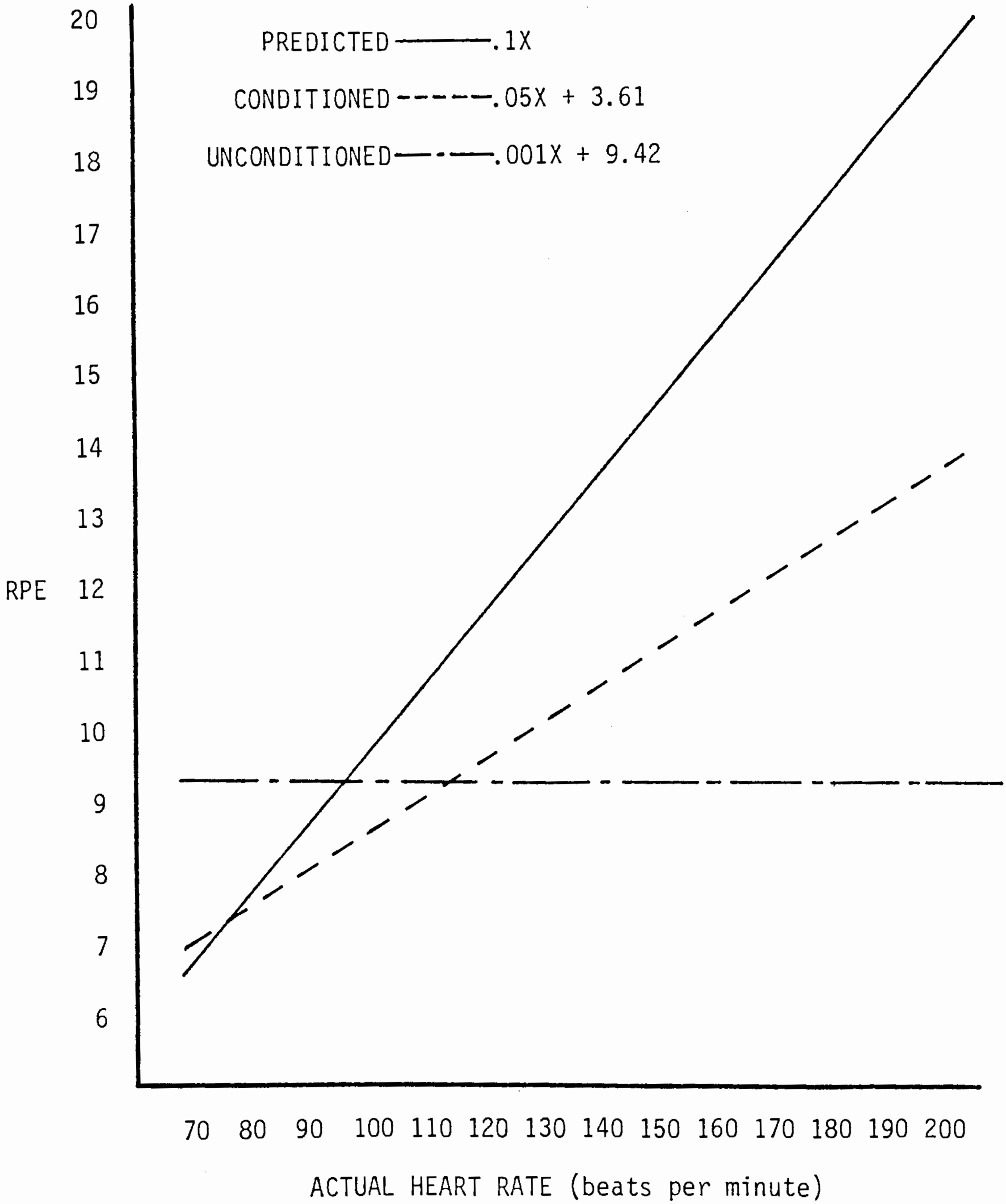

Figure 8. Borg's predicted line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 20% of HRR using the motor driven treadmill.

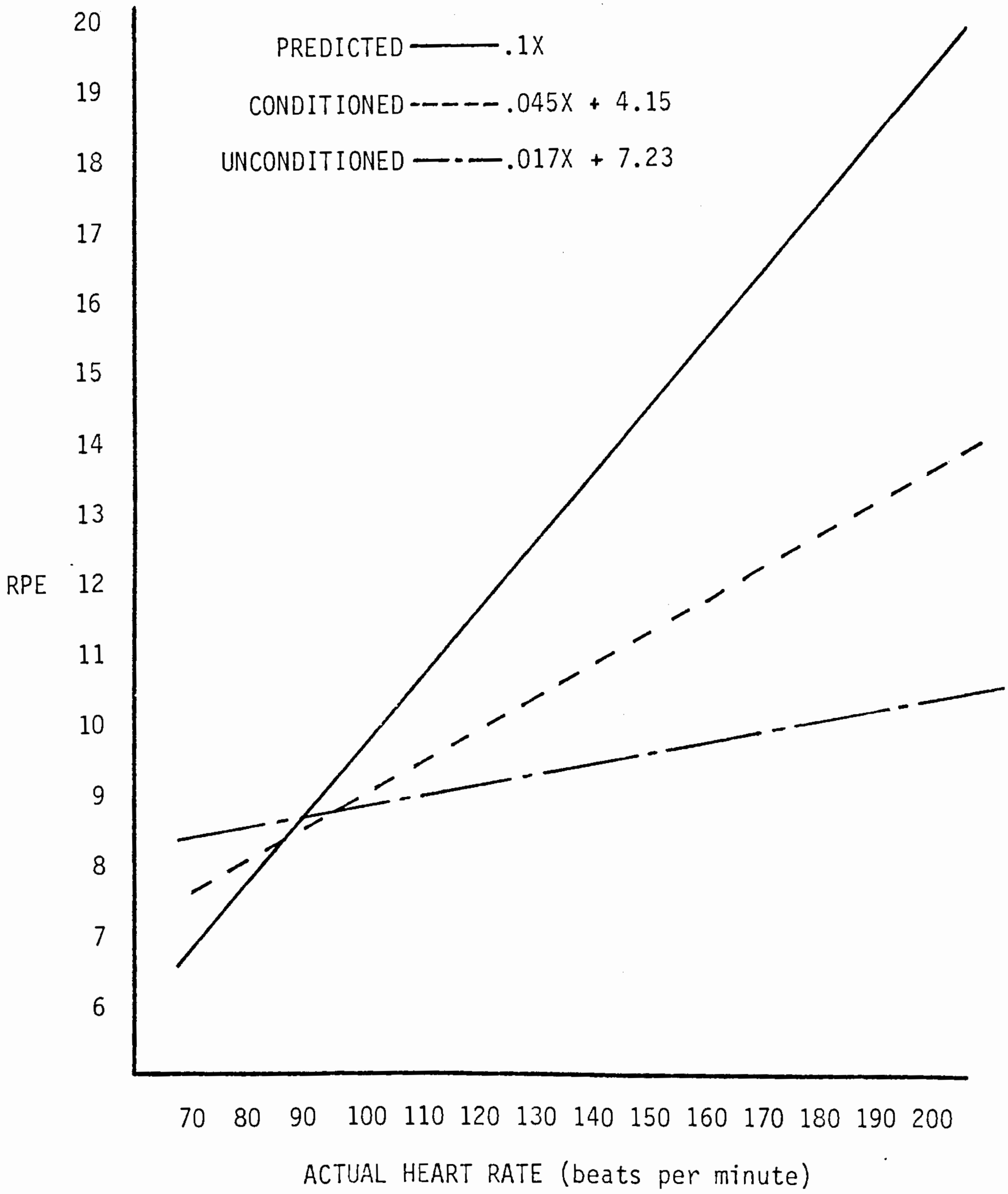

Figure 9. Borg's predicted line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 20% of HRR using the bicycle ergometer.

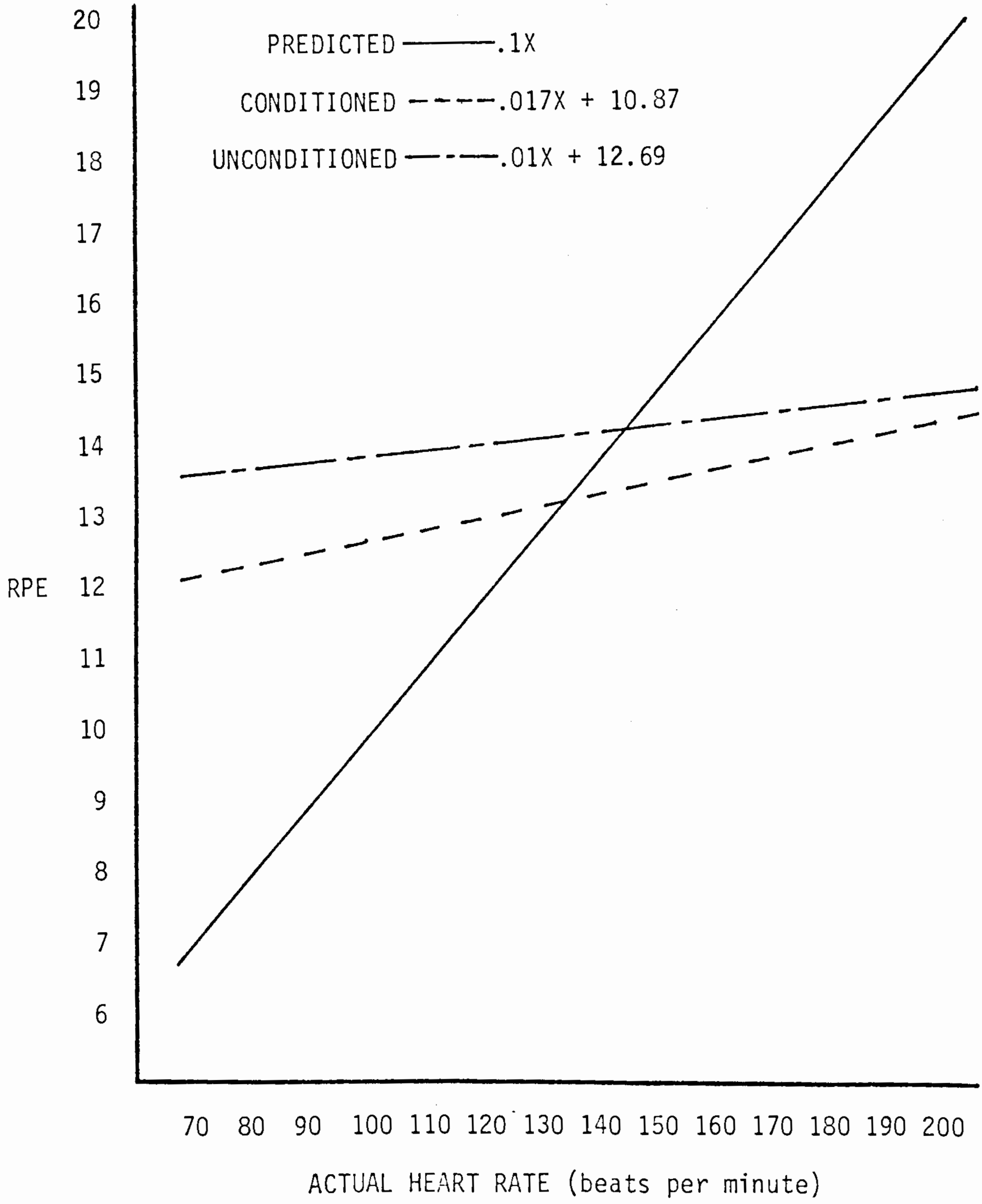

Figure 10. Borg's predicted line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 60% of HRR using the motor driven treadmill.

parison of slopes between groups were 65.57 $p < .05$ for the bicycle and 14.89 $p < .05$ for the treadmill. The range in RPE values for the unconditioned group was from 13.6 to 14.7 and 12 to 14.3 for the conditioned group. In Figure 11, the ranges of RPE for the bicycle at the 60% level were 12.5 to 15 for the unconditioned group and 10.8 to 15.2 for the conditioned group. The higher ranges of RPE on the bicycle are in agreement with previous studies by Ekblom and Goldbarg (1971) and Stamford and Noble (1974) who showed RPE ratings to be higher for a given HR when working on a bicycle. The significant differences between slopes of the two groups lends support to the major contribution of local factors to overall RPE ratings. Borg (1977) determined trained individuals were better perceivers than untrained. The trained subjects were more sensitive to minor changes in stress and strain. A comparison between modes of exercise also indicated a greater sensitivity to workloads on the bicycle versus the treadmill for both groups.

At the final 85% level, using the treadmill, the conditioned group had an RPE range of 15.4 to 16.6 (Figure 12). At this level, the conditioned group was less sensitive to HR changes than the unconditioned group, as illustrated by the slopes of the regression equations. The unconditioned group had an RPE range of 14.8 to 17.6. T-values were calculated and revealed significant difference between groups on the treadmill with a T-value of 111.11 $p < .05$. These results at the 85% HRR level are in opposition to recent literature. Simon et al. (1983) reported trained subjects rated effort higher than untrained

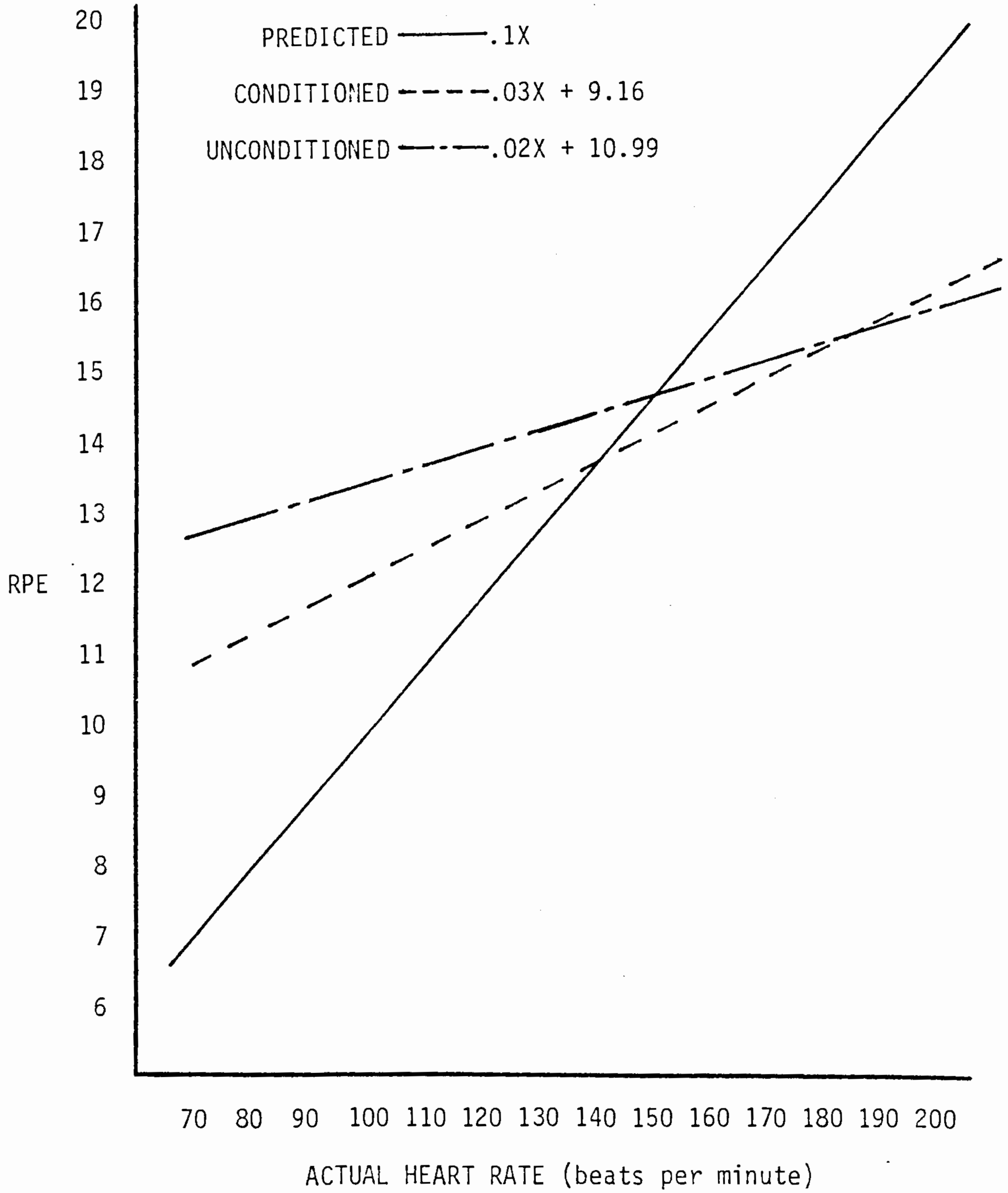

Figure 11. Borg's prediction line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 60% of HRR using the bicycle ergometer.

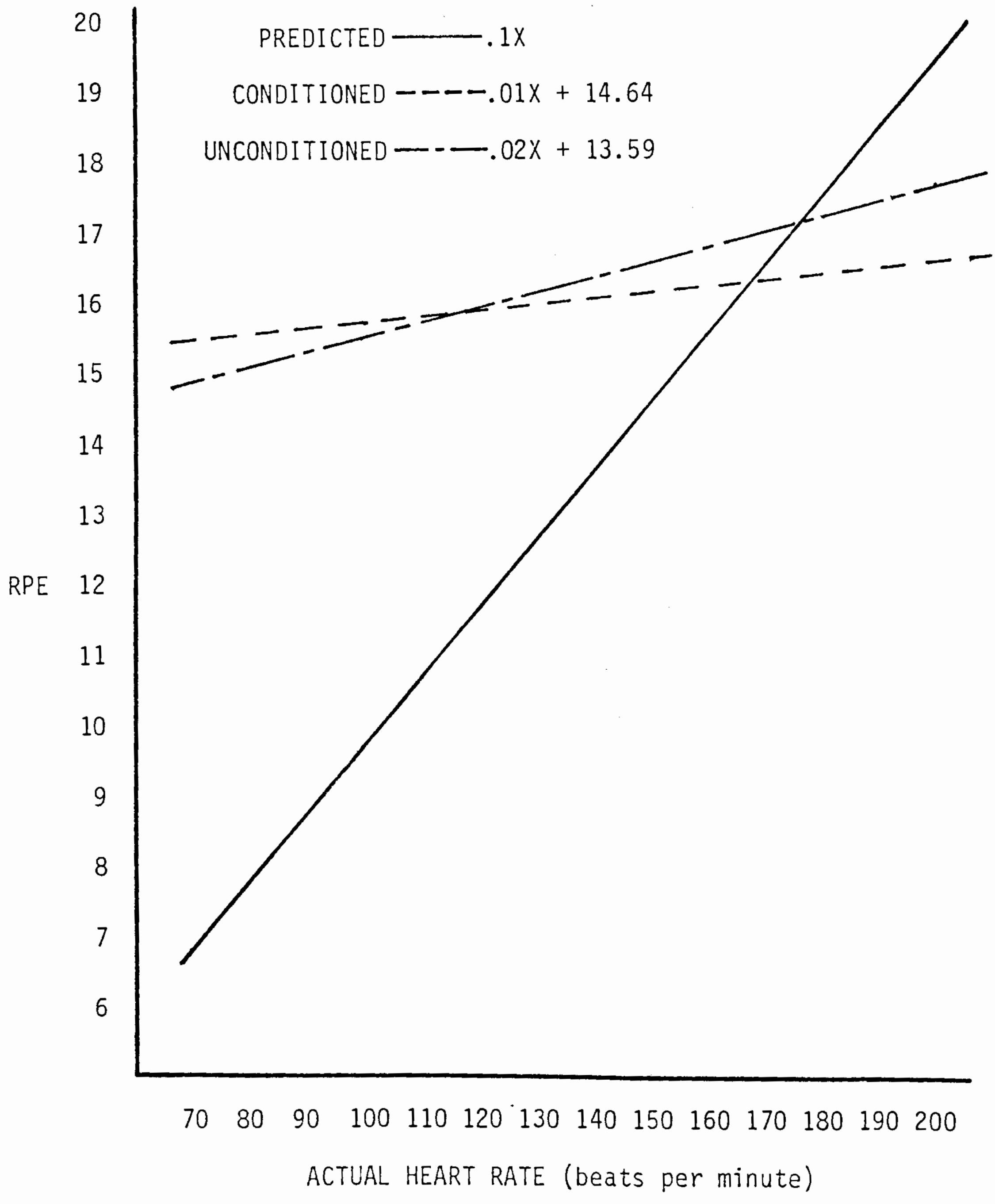

Figure 12. Borg's prediction line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 85% of HRR using the motor driven treadmill.

subjects. Greater emphasis of muscular force used during exercise was concluded to be the reason for the higher ratings. The perceptions of the conditioned group in this study may be responsible for this difference. Being familiar with training levels equal to 70-85% HRR, they were very consistent in eliciting an actual HR corresponding to the assigned RPE.

Figure 13 shows the regression lines and equations for the 85% level on the bicycle ergometer. A T-value of 0.00 was determined, indicating no difference in the slopes of the two groups. However, the conditioned group had an RPE range of 11.5 to 15.2 compared to an RPE range of 13.8 to 17.8 for the unconditioned group. At this level, the unconditioned group estimated actual HR to be higher than the conditioned group, while both groups were equally sensitive in detecting HR changes. As compared to the conditioned group, the unconditioned group, unfamiliar with working at the 85% HRR level, underestimated their HR at the assigned RPE value and they were not consistent in actual HRs recorded for this level. This again, is in support of the local factors carrying an important role in determining overall RPE.

A comparison between modes of exercise was then established. Pearson correlation coefficients between modes of exercise for each workload in T_2 and the assigned RPE values are shown in Table 4. These correlation coefficients range from $r = .55$ for the RPE 85% and HR 85% on the treadmill to $r = .77$ for RPE 85% and HR 85% on the bicycle ergometer. Actual HRs for each mode of exercise were correlated as well and ranged from $r = .70$ for HR 85% to $r = .85$ for the HR 20%.

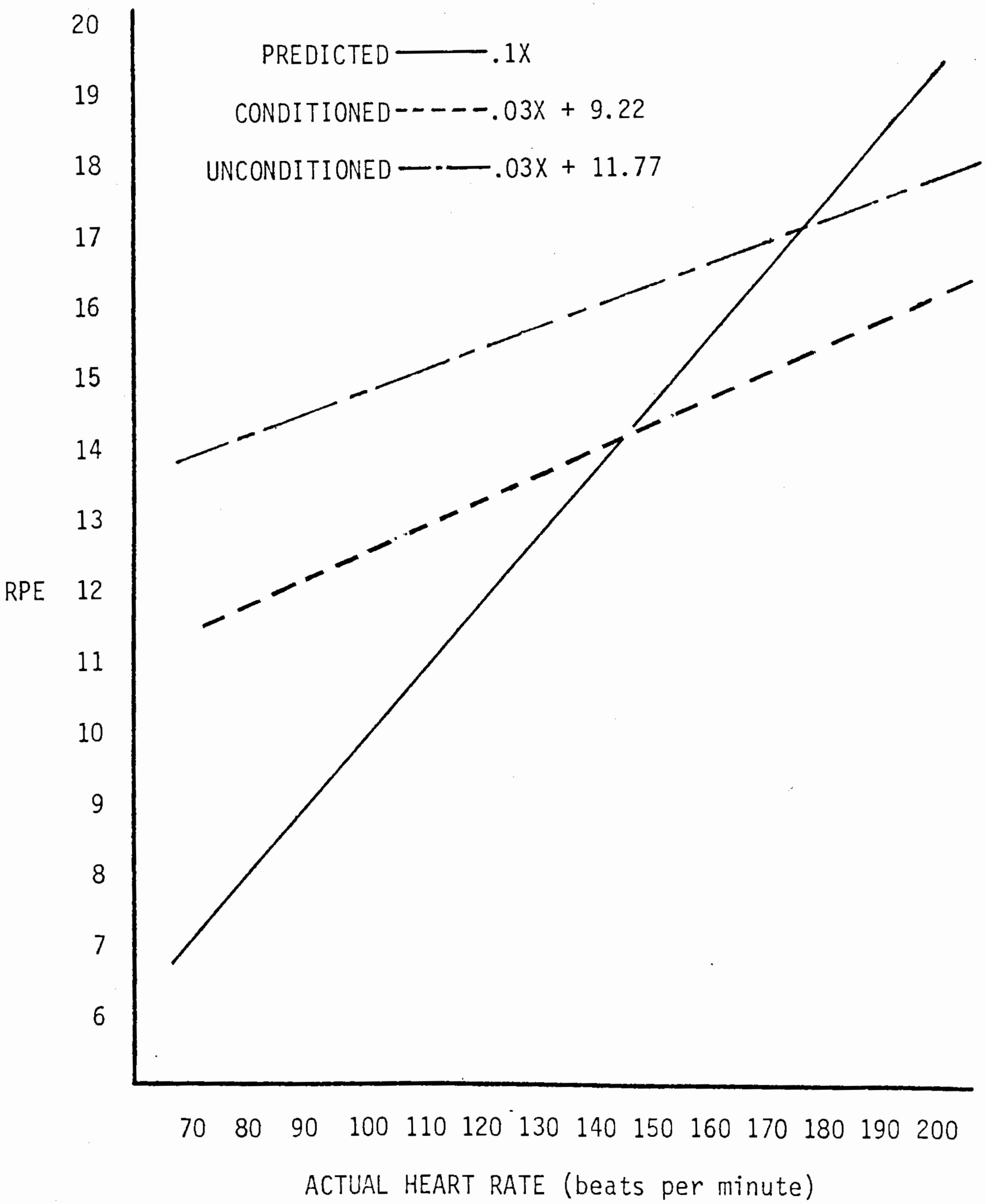

Figure 13. Borg's prediction line (Borg, 1973) along with regression lines and regression equations for the relationship between HR and RPE for T_2 at 85% of HRR using the bicycle ergometer.

These correlations indicate little difference between modes of exercise within the same group. However, a comparison between groups shows the unconditioned group constantly higher in actual HR than the conditioned group. Investigations by Stamford (1976) and Komi and Karppi (1977) are in agreement with these data. They both found no significant differences in peak RPE values of a variety of exercise modes as well as suggesting RPE as a valid and reliable measure of perceived exertion.

In an attempt to compare modes of exercise at the various levels, an analysis of variance between groups on the treadmill and bicycle revealed a significant difference between the groups. These comparisons were made for all the HR values on the bicycle ergometer and the HR 20% value on the treadmill (Table 5). The F value for the HR 20% variable was 24.102 on the treadmill and 25.560 on the bicycle. The F values for the bicycle ergometer for the HR 60% variable was 21.037 and the HR 85% variable was 11.510. The HR 60% and HR 85% variables were not significant at the .05 level on the treadmill. This also is consistent with the emphasis of local factors on overall RPE ratings. A general concensus of the subjects in both groups was a greater feeling of leg stress in the quadraceps muscles while cycling as opposed to running on the treadmill. The overall familiarity with running to all subjects versus cycling could also account for some of the differences between groups on the bicycle ergometer and not on the treadmill.

Table 4

A statistical analysis of the correlation coefficients between modes of exercise and their relationship to RPE for each pair of correlated variables.

Correlated variables	Number of responses	Correlation coefficients	P
HR20%B-HR20%T	20	.8546	0.000
HR60%B-HR60%T	20	.7410	0.000
HR85%B-HR85%T	20	.7039	0.000
RPE20-HR20%B	20	.6509	0.001
RPE20-HR20%T	20	.5936	0.003
RPE60-HR60%B	20	.7339	0.000
RPE60-HR60%T	20	.5806	0.004
RPE85-HR85%B	20	.7669	0.000
RPE85-HR85%T	20	.5469	0.006

Table 5

Analysis of variance between groups of subjects for trial 2 on the treadmill (T) and bicycle ergometer (B).

Variable	Mode	Number of subjects	Sum squares	F value	Probability
HR20%	T	20	4925.823	24.102	0.000*
HR20%	B	20	7319.823	25.560	0.000*
HR60%	T	20	1896.891	4.209	0.055
HR60%	B	20	3985.091	21.037	0.000*
HR85%	T	20	1348.463	3.982	0.061
HR85%	B	20	2124.546	11.510	0.003*

*$p < .05$

CHAPTER V

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

The purpose of this study was to determine if the cardiovascular condition of college age women affects their ability to perceive efforts of work on a bicycle ergometer and a motor driven treadmill at submaximal workloads under normal conditions. It was hypothesized that cardiovascularly conditioned women of college age with a $\dot{V}O_2$ of 45 ml/Kg·min^{-1} or more and a history of training could subjectively perceive efforts better than unconditioned women of college age with a $\dot{V}O_2$ of 40 ml/Kg·min^{-1} or less and no history of training. It was also hypothesized that the accuracy of perceived exertion ratings would increase at higher workloads with all subjects. A maximum HR value was established for each subject. Then, using the Karvonan Principle, three assigned RPE values were used to elicit levels equal to 20%, 60% and 85% HRR during T_2. Relationships were established between RPE and HR for each workload during T_1 and T_2. These relationships were also used to identify the strength or magnitude of RPE to HR on the bicycle ergometer and motor driven treadmill for T_2. A second relationship was also determined comparing RPE and HR between groups for T_2.

Conclusions

Perceived exertion has become an important emphasis for those individuals active for the first time in many years or those in preventative or rehabilitative programs. With this increased popularity in activity, the demand for a better understanding of how people perceive effort is important.

In view of the results of this study, the following conclusions are warranted:

1. College age women who are in better cardiovascular condition can perceive effort more accurately than unconditioned women of the same age. Conditioned women are capable of reproducing a desired level of intensity reflecting HR, using RPE as a means of judgment for levels of 60% max HR difference, and 85% max HR difference better than the unconditioned women of the same age.

2. Women of college age, regardless of their condition, do not accurately perceive efforts of work equaling a 20% level of max HR difference. However, ratings of perceived exertion are more accurate as the level of intensity increases.

3. Conditioned women of college age perceive HR differently than unconditioned women of the same age levels equal to 20%, 60% and 85% of max HR difference on a bicycle ergometer and 20% of max HR difference on a motor driven treadmill.

4. Conditioned and unconditioned women, when combined, showed high correlations between modes of exercise and RPE values related to actual HR at all levels of exercise.

Implications

The concept that increasing cardiovascular condition through training can improve one's ability to subjectively estimate actual HR using RPE has some practical application to physical work capacity on a bicycle ergometer and a motor driven treadmill. These findings, along with the interplay of several contributory factors, are seen to be critical in the determination of RPE. The ratings by individuals during bicycle ergometry from the results of this study emphasize the contribution of the local factor. This local factor, which associates feelings of stress and/or pain in the working muscles and joints, most likely includes several components. Sensations from the ligaments and joint capsules involved along with proprioceptive muscle and tendon sensations would combine to account for the majority of this local factor. This local factor is somewhat less important with walking and running due to greater muscle mass involvement. This subjective regulation of work intensity by perceived exertion alone as investigated in this study shows potential for its use in an exercise prescription setting using normal, healthy females. Unless the level of intensity on the treadmill is 60% of max HR difference and 85% of max HR difference on the bicycle ergometer for unconditioned individuals, RPE alone is not an accurate predictor of HR. For individuals with limited exercise capacity, such as cardiac patients in whom accurate HR values may be a life or death matter, or those with restricted maximum HR values due to age, this method has only limited value.

Recommendations

The following recommendations for future study are presented on the basis of this study:

1. To investigate specific levels at which cardiovascular conditioned individuals begin to accurately perceive HR.

2. To identify to what degree training would be enhanced by feedback, such as knowledge of results at all workloads, if training does include a learning effect on how to perceive the local and central factors of RPE.

3. With respect to specificity of training, to investigate if individuals trained on a bicycle ergometer rather than a treadmill would perceive running to be more difficult than cycling.

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APPENDIX A

INFORMED CONSENT

Title of Research: "Influence of Cardiovascular Condition of Women on Perceived Exertion During Submaximal Workloads"

Principle Investigator: David Bacharach
Graduate Assistant - Cardiac Rehab.

Explanation of Test: The purpose of this study is to determine if the cardiovascular condition of college age women affects their ability to accurately predict HR at a variety of workloads using Borg's RPE scale and to determine what effects different levels of work have on the accuracy of RPE. You will be asked to perform on a bicycle ergometer. Workloads will start at 50 watts and will increase 50 watts every five minutes. The investigator will stop the test when maximum HR is achieved. At every workload you will be asked to rate your level of exertion. On a second day you will return and perform three separate workload trials. At each of these levels you will adjust the workload to equal the assigned RPE on the ergometer and treadmill.

Risks and Discomforts: During the tests you are expected to perform near maximal capacity for determining maximum HR values. In doing so, you may experience some muscle discomfort and/or shortness of breath. These are only temporary conditions. Emergency equipment and trained personnel are available to deal with unusual situations which may arise.

Your participation in this study is voluntary and you may discontinue participation at any time. You have the right to ask any questions about the study and are encouraged to inquire as to any procedure that is unclear. Data obtained from this study will be used for analysis purposes only and will not be released to anyone other than the investigator without your permission.

If you have any questions about the research or your rights as a subject, you may contact the UNI graduate College office at 273-2748.

I am fully aware of the nature and extent of my participation in this project as stated above and the possible risks arising from it. I hereby agree to participate in this project.

______________________________ ____________
(signature of subject or responsible agent) (date)

____
(printed name of subject)

____
(signature of investigator

APPENDIX B

VERBAL INSTRUCTIONS FOR ELICITING A RESPONSE FROM BORG'S RATING OF PERCEIVED EXERTION SCALE

The following instructions were administered to the subjects:

During the last 30 seconds of each workload, the researcher will ask you to indicate to them a subjective rating of how hard you feel you are working. A 2 foot by 3 foot chart will be held in front of you and you should point to the number which best describes your overall perception of effort at that time. Since you will not be able to speak, once you have pointed to the correct number, the researcher will repeat that number to you. If the number is correct you should show a sign of approval by a "thumbs up" gesture. If the number is repeated incorrectly, you must repoint to the correct number, and again give a sign of approval when correct. The question for eliciting your response will be, "At what level are you now?" or "Rate your exertion."