THE INFLUENCE OF MODE OF TRAINING AND GENDER ON BORG'S RATING OF PERCEIVED EXERTION IN CARDIAC REHABILITATION

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Chris Carruthers ©

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ABSTRACT

Title of Thesis: The Influence of Mode of Training and Gender on Borg's Rating of Perceived Exertion in Cardiac Rehabilitation

Thesis Advisor: Dr. Thomas M.K. Song, Professor
Lakehead University

Author: Chris Carruthers

The influence of gender and training mode (treadmill, cycle, swimming and volleyball) on Borg's Rating of Perceived Exertion (RPE) and heart rate was investigated in a Phase III cardiac rehabilitation program. Twenty-three patients with ischemic heart disease (IHD) participated for eight months in a triweekly 60 minute exercise session where RPE and heart rate were monitored at peak activity. The results indicated that both male and female IHD patients have equal ability to perceive effort. A significant difference ($\underline{p}>.05$) was found in the influence of training mode on both RPE and heart rate in the case of volleyball, although the subjects were required to train on all four modes within a narrow heart rate range. An analysis of individual trends showed that certain subjects were able to rate RPE consistently with heart rate over all four modes, while others were not. Overall the subjects were consistent at rating RPE within a narrow heart rate range (12 beats per minute) 66% of the time. These findings reveal that RPE is a valid general indicator of work intensity on various modes. It is recommended that the RPE scale be used with caution for IHD patients requiring strict monitoring of exercise intensity, and that it be used for intraindividual comparisons only.

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Danielle, your influence was felt daily, and I love you.

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CHAPTER 1

INTRODUCTION

STATEMENT OF THE PROBLEM

The purposes of this study were to investigate the use of Borg's Rating of Perceived Exertion (RPE) in a Phase III cardiac rehabilitation training program, to test the relationship between a person's RPE and their heart rate value during four various types of exercise, and to evaluate the differences in RPE in male and female participants.

SIGNIFICANCE

Documentation is abundant on the effectiveness of stationary cycling and treadmill walk/jog activities as training modalities for the healthy population (Pollock, Dimmick, Miller, Kendrick & Linnerud, 1975), and for cardiacs (Kavanagh, 1985; Wilson, Fardy, & Froelicher, 1981). Games such as volleyball provide a recreational alternative. There exists a lack of information on swimming as a feasible activity in cardiac rehabilitation. Swimming is especially beneficial over most other types of aerobic exercises because it utilizes the arm muscles. Upper body training may be important for occupational rehabilitation of the coronary patient (Meyer, 1984). Also, swimming may be the recommended mode of training for the asthmatic cardiac patient due to the humid environment of a pool setting (Samsoe, 1984). But it may be difficult for an obese cardiac patient to expend enough energy in the pool as opposed to land exercise, due to his/her their increased buoyancy (Samsoe, 1984). Magder, Linnarsson, and Gullstrand (1981) found that swimming was more vigorous than bicycling for IHD patients, and that there was a decreased awareness of ischemic symptoms when skill level was low.

Borg's scale is widely utilized in cardiac rehabilitation training programs (Kavanagh, 1985; Hall & Wilson, 1982; Hage, 1981). It has been applied to various groups of subjects such as athletes, the elderly, younger people with low work capacity, and to patients with hypertension or coronary insufficiency. It has also been used to evaluate pain of angina and intermittent claudication in those with circulatory deficiencies (Eklund, 1977). Many exercisers find the scale helpful since it is difficult to describe effort or pain verbally (Borg, 1982).

Recently careful attention has focused on the methods underlying target heart rate derivation, and the merits and limitations of selected exercise modalities (Franklin, Hellerstein, Gordon, & Timmis, 1986). For those anxious about their functional capability, what they perceive and think they are doing is far more influential than what they may actually be doing. This phenomenon explains why a runner drops out of a race or continues, or why an elderly IHD patient continues to pedal the bike or stop.

The ability to sense exertion is of adaptive significance (Borg, 1977a). To exert maximally for every task would be inefficient and exhaustive, so exertion level is adjusted to the performance required. This may indicate the biological basis for understanding the remarkable accuracy and consistency in the human subject's ability to be aware and give accurate quantitative estimates of their exertion levels.

What is the value of RPE and what information is it giving? How can it be used to advantage? Can it be used to assess exercise intensity, monitor progress, and prescribe various types of exercise?

A close correlation between heart rate and RPE will allow the use of RPE to monitor progressive increments in training effect and fitness level. Perhaps the RPE could also be used to monitor exercise intensity and to prescribe exercise. And for those on beta-blockade medication, the investigator requires a determinant of exercise intensity besides heart rate. Subjective RPE values and objective heart rate values taken into consideration together give a better prediction of aerobic working capacity than either one of them separately (Kavanagh, 1985).

This study investigated the reproducibility of Borg's rating of perceived exertion (Borg, 1977b) (Appendix A). It also evaluated the effect of mode of training on RPE, and evaluated RPE differences in male and female patients. The training modes were treadmill walk/jogging, stationary cycling, swimming, and volleyball. The investigation attempted to determine whether RPE cues in on cardiovascular stress at the intensity of exercise most cardiac patients perform.

This study attempted to determine if RPE does reflect the physiological responses to exercise stress on various modalities utilized by IHD patients (Hellerstein, 1984). RPE could be a valuable tool for patients to transfer from one exercise mode to another, increasing their enjoyment of a variety of programs, and offsetting boredom and monotony which often causes decreased adherence to the exercise regimen (Kavanagh, 1985).

DELIMITATIONS

1. Twenty-three participants in a local Phase III cardiac rehabilitation program served as subjects, ranging from 37 to 65 years of age. Sixteen were male and seven were female.

2. Dependent physiological and psychological variables were heart rate and Borg's rating of perceived exertion.

3. Raw data was collected during the period of September 23, 1985 - May 15, 1986.

LIMITATIONS

1. The subjects in this study participated on a voluntary basis.

2. The subjects attempted to exercise at approximately 60% of achieved heart rate on their most recent stress test.

3. The subjects' achieved heart rate on their most recent stress test was assumed to be a reasonable estimate of their peak heart rate.

4. The subjects understood Borg's RPE scale and rated as accurately as possible their subjective exertion level.

5. An RPE value describing an exertion level within a heart rate range of 12 beats per minute was considered consistent.

6. An alpha level of .05 was established as the level of significance for statistical testing.

DEFINITIONS

Angina - Chest discomfort or pain due to ischemia caused by obstructed or narrowed coronary arteries (Katz, 1977).

Angioplasty - Plastic repair of blood vessels through the femoral or brachial artery (Miller & Keane, 1972).

Atherosclerosis - Degeneration and hardening of the intimal layers of the arteries of the cardiovascular system (Miller & Keane, 1972).

Beta-blocker - A commonly prescribed medication for various cardiovascular disorders which decreases the oxygen requirements of the myocardium by blocking beta-adrenergic receptors with a negative chronotropic effect (Katz, 1977). Heart rate measures are invalidated by regular beta-blockade medication.

Consistency - An RPE value describing an exertion level within a heart rate range of 12 beats per minute (Shephard et al., 1979).

Dysrhythmias - Disturbance of heart rhythm (Miller & Keane, 1972).

Heart rate - The number of contractions of the cardiac ventricles per unit time (Miller & Keane, 1972).

Inconsistency - An RPE value describing a range of exertion over 12 beats per minute and under 25 beats per minute (Shephard et al., 1979).

Ischemic heart disease (IHD) - A condition characterized by a deficiency of blood supply to the myocardium, usually caused by atherosclerosis of the coronary arteries (Miller & Keane, 1972).

Maximal oxygen uptake ($\dot{V}O_2$ max) - The maximum amount of oxygen which can be consumed per unit of time by a person during a progressive exercise test. It can be reported as an absolute value (l/min) or a relative value (ml/kg/min) (MacDougall, Wenger, & Green, 1982).

Phase I cardiac rehabilitation - An in-patient program begun about three days after the cardiac event, consisting of low intensity exercise to allow performance of daily life activities. This will progress gradually to upper body exercises, walking, and stair climbing. An educational program for patient and family on IHD treatment and risk factors is begun. This in-hospital period is usually 10 - 14 days in length (Wilson et al., 1981).

Phase II cardiac rehabilitation - A medically supervised out-patient program, beginning the second or third week post-event and lasting three to four months. The exercises consist of upper body work, and aerobic and interval training. The exercise prescriptions are based on results of stress tests performed on completion of Phase I of rehabilitation. The prescriptions are monitored closely with adaptations for continued progress. The educational program also continues (Wilson et al., 1981).

Phase III cardiac rehabilitation - A community based program supervised by cardio-pulmonary resuscitation trained nurses or physical therapists who have emergency equipment and medications on hand. It consists of activities of various forms, often including treadmill walk/jogging, stationary cycling, swimming, and other games, plus strength and flexibility exercises (Wilson et al., 1981).

Rating of perceived exertion (RPE) - A subjective value of work intensity, consisting of a 15 point category scale ranging from 6 - 20, with a descriptive verbal anchor at every odd number. The rating of perceived exertion correlates well with various physiologic factors such as heart rate, minute ventilation, oxygen consumption, and blood lactate concentration, and is therefore a reliable and valid indicator of the level of physical exertion and relative fatigue (Borg, 1982; Pollock & Pels, 1984).

CHAPTER 2

REVIEW OF LITERATURE

Total cardiac rehabilitation is the process of restoration to optimal physical, social, emotional, and vocational status after a cardiac event. Lifestyle risk factor modification is the primary aim of rehabilitation programs. This includes measures to prevent, retard, or reduce the underlying atherosclerotic disease process (Hellerstein, 1984). Ischemic heart disease (IHD) is a pathological condition resulting from atherosclerosis. It develops slowly over decades, and for a considerable amount of time it may be asymptomatic.

Risk factors for IHD are well documented, and include factors not modifiable such as age, sex, and genetic predisposition, and those which may be modified, including smoking, high cholesterol levels, diabetes mellitus, lack of physical activity, obesity, hypertension, and emotional stress (Wilson et al., 1981; Hellerstein, 1984; Kavanagh, 1985).

The literature is replete with evidence that exercise has a beneficial effect on the cardiovascular system of patients with IHD (Kavanagh, Shephard, Chisholm, Qureshi, & Kennedy, 1979; Paterson, Shephard, Cunningham, Jones, & Andrea, 1979; Franklin, Wrisley, Johnson, Mitchell, & Rubenfire, 1984). The greatest benefit of exercise seems to be increases in anginal threshold and functional capacity, probably due to non-cardiac adaptations (Froelicher, 1983). Many researchers have further explored the contribution of various types of exercise programs in patient rehabilitation (Shephard, Corey, & Kavanagh, 1981).

Exercise is an important aspect of all three phases of rehabilitation (Hellerstein, 1984). Exercise may also relieve depression (Kavanagh, 1985), which is common and is usually caused by the threat of invalidism and the loss of autonomy and independence. Therefore teaching the patient to be comfortable with exercise at a certain intensity relieves his or her anxiety about activities of daily life, enables them to function comfortably, and may alleviate much of the depression (Hall, 1984).

CARDIAC REHABILITATION PROGRAMS

Successful cardiac rehabilitation programs seem to be organized in a similar manner. Patients must be referred through their physician, undergo an initial stress test, and exercise under medical supervision. Most directors of programs seem in agreement that the reduced aerobic capacity of the post-myocardial patient is significantly influenced by training intensities of 40-60% of maximum (Boone, 1986).

The Toronto Rehabilitation Centre (TRC) boasts a record of one exercise-related death per 340,750 person hours of exercise (Kavanagh, 1982). The patients are stress tested initially by three progressive stages of three minutes duration on the cycle ergometer to 85% of predicted aerobic power. Stress testing is repeated at six month intervals. The patients are given a walk/jog prescription from training tables and then exercise once per week for one hour at the Centre and four times per week at home. A nomogram is used which outlines how to progress with exercise intensity. The TRC also has an extensive IHD education program, including psychological and personality profiles. Also available are an occupational upper body rehabilitation program, home programs, and the TRC jogging club.

Based at the University of Washington, the Capri Exercise Program uses an initial Bruce protocol treadmill assessment (Bruce, Kusumi, & Hosmer, 1973) with re-evaluation after a three times per week, one hour duration exercise program (Hartwig, 1982). The stress test is repeated about five months after entry, then yearly after that. The exercise modes used are walk/jogging and stationary cycling at a training heart rate of 70-85% of the individual's maximum heart rate at the last stress test (Hartwig, 1982).

The LaCrosse Exercise Program Cardiac Rehabiliation Unit in Wisconsin offers adult fitness, a Phase III cardiac rehabilitation program, and also a non-physician supervised conditioning program for IHD patients (Hall & Wilson, 1982). Patients are initially given a broad diet evaluation and a treadmill stress test. The exercise test is repeated at three, six, and nine month intervals, and each year thereafter. The modes of exercise used are walk/jogging, cycling, water walking, or swimming. Exercise intensity is begun at 60 - 70% of heart rate reserve, and performed three times per week for one hour.

RATINGS OF PERCEIVED EXERTION

In order to quantify self-reported, subjective estimates of effort expenditure during exercise, RPE is often used

(Hage, 1981). The concept of perceived exertion presupposes that the average individual can relate body signals such as heart rate, breathing rate, blood pressure, oxygen consumption, and blood lactate level to a given intensity of exertion (Kavanagh, 1985). By re-creating these signals, he or she can reproduce that same level of exertion under varying conditions. Ratings of exertion are also used when drugs or arrhythmias preclude consistency in heart rate response to exercise (Hall & Wilson, 1982).

Perceived exertion during physical performance has been under study for four decades. The RPE can be considered a complex Gestalt; an integration of many phenomena and signals (Borg, 1977a). It is based on both physiological and non-physiological components, and therefore requires an interdisciplinary approach.

Using ratings of perceived exertion, physiological and psychological data can be interpreted to make the best prediction of gross psychomotor performance. RPE can valuably supplement objectively measured variables.

A convergence of information from several afferent channels is necessary for conscious judgement of motor performance. The relative contribution of proprioceptive and metabolic factors depends on the duration and intensity of the work. In short or light work, proprioceptive sensations related to force and velocity dominate. In heavier, longer duration work, metabolic factors (from circulatory, respiratory, and possibly muscular metabolism) dominate (Carton & Rhodes, 1985).

In the first three minutes, local factors are the primary signals of exertion. After this, central cues contribute especially at lower work intensities. The manner in which sensory inputs are monitored and integrated remains unclear (Mihevic, 1981; Cafarelli, 1982). The muscle sense is not as self-supporting nor as well organized as the visual, auditory or tactile senses.

Pandolf (1978) feels that differentiated ratings of perceived exertion will clarify the interplay of the two factors. For example, a treadmill subject would rate his upper body cues separately from his lower body cues. But in a field setting, research does not support a central control model for peceived exertion based on cardiovascular stress (Jackson, Dishman, LaCroix, Patton & Weinberg, 1981).

The most well-known work in the field of perceived exertion has been contributed by Borg, a Swedish physiologist. He noted an obvious fundamental relationship between physiological indicators of physical stress and a psychological indicator, RPE (Borg, 1973). He originally developed a 21 point categorical rating scale with verbal expressions corresponding to different levels of effort during aerobic work (Borg, 1977b). The scale was based on a correlation of 0.80 to 0.90 between perceived exertion and heart rate during light to heavy exercise on a cycle ergometer. He later adapted a scale of 15 points to increase the linearity between the ratings and the workload (Borg, 1977b). The RPE values on this scale were found to be approximately one-tenth of exercise heart rate values for healthy male men performing moderate to heavy exercise.

Quantifying effort may be accomplished by using either ratio or category scales. When psychophysiological variables are being considered, one must carefully consider that the measuring system can accommodate the values used for comparison. When determining change, ratio scales should be used, but when making differential observations, category scales of the interval type are useful (Borg, 1977a). A ratio scaling method developed by Stevens at Harvard in 1957 and 1966 (Carton & Rhodes, 1985) has an absolute zero point and values spaced at an equal distance from one another. A ratio scale allows summation of different sensations to examine overall effects.

Borg's category scale is not additive. It does not give absolutely true values in a physical or mathematical sense, but these values do provide a description of differences. It allows direct differential level comparisons and also permits interindividual comparisons (Borg, 1977a). The category scale was constructed to increase linearly with workload. The ratio scaling procedure is a positively accelerating function with an exponent of 1.6. Therefore there is a non-linear relation between the ratio scale and the category scale (Carton & Rhodes, 1985).

Borg's category scale is practical and broadly applicable, especially for exercise participants who have limited ability with numbers. It can also be used to define the subject's exercise tolerance limit (Turkulin, Zamlic, & Pegan, 1977). Recently in 1982 Borg developed a new 10 point category scale with ratio properties where, for example, the value of 4, representing "light" work, is twice as difficult as the work done at a value of 2. Perceived exertion increases exponentially using this scale. This scale is especially applicable for rating anaerobic activity, and may be suitable for rating other subjective symptoms such as breathing difficulties, aches, and pains (Borg, 1982).

Many studies have attempted to assess the reliability and validity of Borg's scale (Stamford, 1976). Various other scales for perceptual rating of exertion also exist (Carton and Rhodes, 1985).

PHYSIOLOGY OF RATINGS OF PERCEIVED EXERTION

Numerous investigators have tried to identify the sensory cues which lead to cognitive evaluation of effort. The first to identify peripheral factors separate from central ones were Ekblom and Goldbarg (1971), who studied 19 healthy males, 21-32 years of age. They proposed a two factor model for RPE: one local (the working muscle) and one central (the cardiopulmonary system). The central parameters considered include heart rate, respiratory rate, minute ventilation ($\dot{V}E$) and $\dot{V}O_2$.

A study by Noble, Metz, Pandolf, Bell, Cafarelli, and Sime (1973) supported Ekblom and Goldbarg's two-factor theory. They noted that during walking or running at a velocity less than 4.0 miles per hour, perceived exertion while running was greater. The reverse was observed at velocities higher than 4.0 miles per hour. The mechanically inefficient slow running evoked a larger degree of local muscular strain. Noble, Metz, Pandolf, and Cafarelli (1973) hypothesize that the individual tunes in to sensations that result from these physiological processes, such as increases in ventilation, respiratory rate, and skin temperature, which can be directly perceived. After studying the effect of equivalent power outputs and various pedalling speeds on perceived exertion, Pandolf and Noble (1973) noted that sensations particular to the working muscles such as muscular force and muscular and joint discomfort were the important factors affecting effort perception.

The linear relationship between heart rate and RPE is generally conceded. This has been noted for both sexes (Stamford, 1976), various fitness levels (Bar-Or, Skinner, Buskirk, & Borg, 1972; Mihevic, 1983), and on bike or treadmill (Stamford, 1976). As maximum heart rate decreases with age, RPE becomes higher at a given heart rate in older subjects (Bar-Or, 1977).

There is a very close correlation of RPE to strain, as defined by heart rate ($r = 0.888$), and stress, as defined by workload ($r = 0.933$) (Ulmer, Janz, & Lollgen, 1977). Mihevic (1981) also noted that while $\dot{V}O_2$ grows linearly with respect to workload, RPE increased according to a positively accelerating function which closely effects $\dot{V}E$ and blood lactate response curves.

In most work situations, heart rate will mirror the physical strain subjectively experienced. But this good correlation is altered with blocking agents, where a better correlation is seen between RPE and blood lactate concentrations (Ekblom & Goldbarg, 1971).

Beta-blockade medication has widespread clinical use. Maximum heart rate is often no more than 100 to 125 beats per minute for those patients on beta-blockers. The decrease in heart rate varies considerably with dosage (Wilson et al., 1981). Patients on beta-blockers, whose RPE is not affected at given percentages of maximal oxygen uptake ($\dot{V}O_2$ max), demonstrate that heart rate and RPE are not causally related (Ekblom & Goldbarg, 1971). $\dot{V}O_2$ max is affected very little by beta-blockade (5-15%) (Tesch, 1985), therefore patients on such drugs, even though exhibiting a low heart rate, probably can influence a training effect with exercise (Franklin et al., 1984; Wilmore, Joyner, Freund, Ewy, & Morton, 1985).

The physically active cardiovascular patient will benefit more with training if he or she is on cardioselective (B_1 adrenoreceptor) blockade, than from non-selective (B_1 and B_2 adrenoreceptor) blockade (Tesch, 1985). Also, for those patients on calcium slow-channel blocking agents such as Diltiazem or Adalat, a training effect is feasible. Some question the possible training effects of those on beta-blockade (Tesch, 1985; Vanhees, Fagard, & Amery, 1982)). This is probably due to large dosages which may be required if the disease is well advanced (Franklin et al., 1984).

The best way to prescribe exercise for these patients is to conduct an exercise test while the patient is on the medication and develop the exercise prescription accordingly. If medications are changed, the stress test should be repeated to ascertain exercise capacity on the new drug therapy.

In general, RPE values increase more in relation to increasing heart rate in patient groups than in healthy controls (Borg, 1971). Within the first minute of exercise, more than three-quarters of the amplitude of Borg's scale is reached (Ulmer et al., 1977).

The rating of perceived exertion does not seem to be a function of one single physiological parameter, such as heart rate. When heart rate responses were elevated by heat, no significant differences were found in RPE (Ekblom & Goldbarg, 1971). Heart rate is an easy, convenient measurement but it will be altered with climatic extremes, fatigue, or very short or very prolonged exercise (Skinner, Hustler, Bergsteinova, & Buskirk, 1973). Heart rate can be modified in hypnosis or with pharmacological treatments. It can also be modified artificially by using heat or negative work. The value may be questionable because it can also be severely influenced by anxiety, smoking, and methylxanthine consumption. High temperatures, such as those experienced by a marathon runner after a competition must make a difference in how he would decide whether he is exhausted or fatigued. Heart rate and RPE may also be dependent on body position and the kind of muscles in action. Pandolf (1978) showed that activities vary in their influence by neuromuscular components.

The rating of perceived exertion data may be used to supplement heart rate information, since self-monitoring of heart rate has its drawbacks. Froelicher (1983) lists the disadvantages of manual heart rate determination. They include time taken to locate the pulse, accuracy in counting, accuracy of timing, and complicating dysrhythmias. Greer and Katch (1982) feel that manual pulse as a substitute for electrically recorded heart rate is a questionable procedure if precision is required. They report that the actual heart rate could be underestimated by 6 - 11%. Shephard et al. (1979) had 323 adult office workers take their pulse concurrently with a criterion heart rate recorded by electrocardiogram (ECG). They reported that modest experience in pulse counting results in a probable random error of about eight beats per minute, with a correlation coefficient of r=0.76 between heart rate and ECG counts with the resting pulse. Greater precision was seen with exercise pulse counts.

There is the question of the safety of the carotid pulse and the accuracy of the radial pulse (Froelicher, 1983; Greer & Katch, 1982; Hage, 1981). In a study of 20 asymptomatic adults, Couldry, Corbin, and Wilcox (1982) compared radial, carotid, and ECG pulse counts. Ten second palpations were not significantly diffferent than those from ECG tracings, and carotid and radial palpations were equally accurate. Witten (1973) found a r=0.95 correlation coefficient between pulses counted manually by the subject and the corresponding ECG count. Gregory (1979) found no significant difference between a manual count and a telemetry count during continuous and interval training when heart rate was recorded at the end of each workload. Zingraf, Squires, and Maneval

(1983) also evaluated heart rate values using an electronic monitor (Exer-Sentry) and the carotid pulse, and found that use of the carotid pulse to determine exercise heart rate resulted in little loss of accuracy.

The IHD patient may be more sensitive to the carotid sinus reflex (Froelicher, 1983). But Boone and Rape (1983) reported that carotid palpation cannot be considered a threat to the post-coronary patient's safety. Patients with peripheral neuropathy may have difficulty palpating their heart rate (Hage, 1981).

Some researchers believe that the heart rate is only an indirect measure of exercise capacity. It may be especially unsuitable for cardiac patients, since submaximal training will result in a training effect in the peripheral system, not on the heart (Hage, 1981). Another way to measure exertion subjectively is to simply ask the participant to estimate their effort as a percentage of maximal intensity. But maximum functions vary tremendously from individual to individual (MacDougall et al., 1982).

EFFECT OF MODE OF TRAINING ON RPE

Stamford (1976) had subjects involved in four different work tasks (treadmill walk, jogging, cycling, and stool stepping) and had them rate exertion during progressive, oscillating, and single load sub-maximal intensities. Heart rate and RPE were taken at either regular intervals or during the final minute of work. He noted high correlations (r=0.90) between heart rate and RPE and high reproducibility of RPE in all situations, especially at terminal ratings.

Horstman, Morgan, Cymerman, and Stokes (1979) found that walking and running at the same relative work intensities resulted in comparable perceptual and physiological responses.

A study by Gamberle (1972) using exercising subjects in weight lifting, wheelbarrow pushing, and cycle ergometry revealed a linear relationship of RPE and heart rate irrespective of the kind of work done. In a study of 19 healthy males, Ekblom and Goldbarg (1971) noted a higher RPE for a given level of oxygen uptake during arm work as opposed to leg work, and during biking as compared to running and swimming. In a progressive exercise protocol, Sidney and Shephard (1977) noted a somewhat lower RPE on treadmill work than on the bicycle ergometer.

Various forms of exercise have different mechanical efficiencies therefore standardization and well defined situations and conditions must be employed (Borg, 1977a).

In a study of perceived exertion during eccentric and concentric contractions on a bicycle ergometer, Henricksson, Knuttgen, and Bonde-Peterson (1972) suggest that exertion during various forms of exercise and under different conditions is perceived or assessed from different combinations of information obtained from both afferent and efferent signals.

EFFECT OF INTENSITY OF WORK ON RPE

Carotid palpation of the heart rate is commonly used in cardiac rehabilitation programs to determine exercise intensity (Oldridge, Haskell, & Single, 1981). Some rehabilitation centres use Borg's scale to monitor a consistent exercise intensity for cardiac patients exercising under various conditions (Kavanagh, 1982).

A study comparing heart rate and rating of perceived exertion reliability during running and walking revealed that exercise above a heart rate of 150 beats per minute, or a running speed above 9 km/hour elicited a closely related RPE. Smutok, Skrinar, and Pandolf (1980) stated that, for healthy subjects, the use of RPE for exercise prescription below this level would result in inaccurate and unreliable conditioning heart rates. Mihevic and Morgan (1982) determined that the absolute workload necessary for detection of changes in exercise intensity was about 15-20 Watts.

Hare, Hakki, Lowenthal, Iskandrian, and Segal (1985) also found a poor correlation between RPE and absolute heart rates at low intensities of exercise where cardiac rehabilitation patients rated leg discomfort and dyspnea. RPE was reproducible at 60%, 70%, and 95% of maximal heart rates achieved during the testing. A study by Christensen and Ruhling (1983) on healthy women revealed that higher pedalling rates in the cycle ergometer and higher walking speeds on the treadmill elicited greater cardiorespiratory and RPE responses than more moderate intensity.

Borg (1977a) found correlation coefficients between heart rate and RPE lower when using "hard" to "very hard" workloads. A light workload seemed to represent a physical dimension and a hard workload a psychophysiological one.

Studying groups of sportsmen, untrained healthy subjects, and myocardial infarction patients, Turkulin et al. (1977) found well-marked differences in rating work intensity, probably due to age. Compared to healthy controls, groups of IHD patients rate exertion higher in relation to heart frequency, particularly at high value levels. Perhaps the low correlations could be explained by relatively low workloads, which may or may not indicate a low work capacity of the whole group (Turkulin et al., 1977). Experiments with progressively increasing loads have to be distinguished from those of steady state work.

Ratings of perceived exertion seem to be similar at the anaerobic threshold of subjects tested. A level of exertion of 13 to 15, recommended for the later stages of cardiac rehabilitation, corresponds to the ventilatory threshold usually occurring at an average RPE of 13.5 for cardiac subjects (Franklin et al., 1986). Noble (1982) has demonstrated that increases in RPE using Borg's 10 point scale correlated closely with incremental elevations in blood lactate.

Noble, Borg, Jacolis, Ceci, and Kaiser (1983) related Borg's new category - ratio scale to physiological parameters in progressive, maximal exercise on the cycle ergometer in physically active males. They found that RPE corresponded well with glycolytic metabolism as measured by blood lactate accumulation. The exponents of the power function were 1.63 - 1.67 for the perceptual variation, 2.2 for blood lactate, and 2.7 for muscle lactate.

The rating of perceived exertion appears valid for those on beta-blockade medication. Similar RPEs are obtained at a given percentage of maximum heart rate reserve, regardless of dosage or peak heart rate (Franklin et al., 1986). Propanolol will increase exercise tolerance and $\dot{V}O_2$ max. In a study of nine coronary artery diseased patients training for 12 - 16 weeks, Koyal, Stuart, Lundstrom, Thomas, and Ellestad (1985) noted an alteration in anaerobic threshold and describe this increase as an effect of increased stroke volume, increased peripheral oxygen extraction, and increased $\dot{V}O_2$ max. Teghtsoonian, Teghtsoonian, and Karlsson (1977) found an increase in RPE variability at very high intensity workloads. Noble, Maresh, Allison, and Drash (1979) demonstrated poor reliability of Borg's scale during recovery from a treadmill run to exhaustion. They suggest development of a scale that approximates more closely metabolic responses during recovery. No data is conclusive on whether perceptual recovery parallels physiological recovery (Noble, 1982).

Reproducibility of work capacity based on RPE appears to be as accurate as that based on heart rate. In studies of self-regulated exercise where subjects were given a RPE to reproduce and were allowed to control the speed of the treadmill, it was found that for exercises above 150 beats per minute, RPE could be reliably used to self prescribe exercise (Smutok et al., 1980).

When Michael and Eckhardt (1972) asked trained and untrained healthy subjects to reproduce a "hard" work intensity at 0^{o} treadmill slope onto a 10^{o} slope, all runners selected workloads which elicited about 80% of $\dot{V}O_2$ and a heart rate of 170 beats per minute. In a cycle test situation, Skinner et al. (1973) found that small variations in intensity could be detected by subjects even when presented in random order.

Pandolf (1978) found a ten beat per minute increase in heart rate and a 0.9 rise in RPE with concentric laddermill work. The eccentric or negative phase of the work did not correlate well with Borg's scale. The highest rating value of Borg's scale seems to be reserved for an exertion level of life or death. Subjects will most often cease working at a perceived exertion value of 17 or 18 (Borg, 1977a).

EFFECT OF AGE ON RPE

It has been well documented that psychological deterioration occurs with advancing age. The central nervous system shows a decline in certain mental abilities such as perception, information processing, decision making, and memory (Stelmach & Diewert, 1977). Perhaps oxygen availability is related to aging decrements. Evidence exists that those with increased cardiovascular function show a lesser decrease in mental capacity (Ohlsson, 1977).

The relationship between RPE values and heart rate changes with age. Older people will rate exertion higher in relation to heart rate than young people (Borg, 1971). The pulse rate necessary to produce a given RPE decreases with age, and that decline is roughly parallel with the decline in maximum heart rate. Therefore the scale provides a measure of relative stress, independent of age (Franklin et al., 1986; Sidney & Shephard, 1977).

Bar-Or (1977) found that the older the subjects, the higher their RPE for a given heart rate, therefore the correlation coefficient between heart rate and RPE is smaller, indicating that they can less "accurately" rate their exertion level. This study was done on subjects free of overt disease. When RPE was compared with percent of maximum heart rate achieved, the differences were less noticeable but still demonstrated. His study established evidence that RPE multiplied by ten enables a fairly accurate estimate of heart rate for middle-aged or older people, but less so for children, adolescents, and young adults. This may simply be that children are perceptually more sensitive than older people.

Arstila, Antila, Wendelin, Vuori, and Valimake (1977) found that, of 441 healthy subjects, the linearity of RPE to heart rate at peak exertion was lower, causing them to conclude that the elderly ones simply stopped the test sooner.

Most research on RPE has been done on younger subjects while clinical applications have been with older subjects. A consideration of any scaling technique applied to heterogenous populations is that day to day variability may occur.

EFFECT OF GENDER ON RPE

Noble (1982) found differences in male and female perceptions of effort as a function of absolute oxygen consumption. But when these values were compared relative to percent $\dot{V}O_2$ max, no differences were apparent. Sidney and

Shephard (1977) also noted ratings were higher for females, but when expressed as a percent of oxygen intake, scores became independent of sex and age.

Arstila et al. (1977) found that the linearity of RPE in relation to heart rate was far better in men than in women. Komi and Karppi (1977) demonstrated in twin studies that heart rate and RPE are not influenced to any significant degree by genetic factors.

EFFECT OF EXERCISE EXPERIENCE ON RPE

Stamford (1976) used 14 sedentary females to test the reliability and validity of perceptual responses. On various exercise tasks of various intensities at various times, the RPE values elicited were closely correlated. These subjects were previously unfamiliar with assessing perceived exertion. A field study by Hogan and Fleishman (1979) who had subjects rate various occupational and recreational activities, found a high correlation between perceptual ratings and the true energy cost of the activity, independent of the sex or previous rating experience of the sample.

Mihevic (1983) concluded that perceived exertion does not discriminate between groups of high and low fit subjects during short term exercise at moderate intensities despite differences in cardiovascular strain. She suggested that the RPE scale not be used for inter-individual comparisons.

With training, a decrease in heart rate was seen at submaximal workloads, and RPE was lower for a given level of oxygen uptake, but the same when related to percent of $\dot{V}O_2$ max (Ekblom & Goldbarg, 1971). The training status of subjects must be taken into account when evaluating changes in RPE scores (Ulmer et al., 1977). The dependency of perceived exertion on the state of physical fitness seems to be low. Only in the higher ranges of stress are found decreased RPE scores with increased fitness (Ulmer et al., 1977).

Self-determined pacing is especially developed in well-conditioned individuals (Borg, 1971). Horstman, Kowal, Vaughn and Stravanelli (1979) feel there is a significant influence of previous exercise experience on the perception of work effort.

EFFECT OF PERSONALITY ON RPE

The largest psychological barrier to rehabilitation after myocardial infarction is the depressed mental state (Friedman, 1976), and therefore special consideration should be given to psychological problems. Three types of behavior are noted by Degree-Coustry (1976); impulsive reactions (minimizing health problems), adapted reactions (realistic control), and regressive reactions (an exaggerated, passive, and fearful attitude). Johnson (1976) stated that control of the cardiac environment during the patient's pathway through rehabilitation will lessen unwarranted psychological reactions.

Friedman and Rosenman (1974) believe that particular Type A personality characteristics such as nervousness, agressiveness, and impatience predispose a person to higher coronary risk. Personality characteristics such as extroversion and introversion may impact strongly on how a person "judges" his perception of effort (Borg, 1977a). An extrovert may underrate work intensity at heavier loads (Morgan, 1973). During lower intensities of work the effect of a person's personality is lessened. The investigator cannot avoid measuring personality to some extent (Borg, 1971). He or she must also avoid bias and avoid forcing subjects to work harder or longer.

Subjects who are neurotic, anxious, or depressed seem to have difficulty in perceptual processing of work intensity, and tend to underestimate the intensity of moderate workloads (Morgan, 1973).

Effort, fatigue, exertion, and strain are of both physiolocial and psychological origin; fatigue could be considered a subjective state (Borg, 1977a). Performance may be very dependent on the degree of motivation, which may effect individuals in various emotional ways (Borg, 1977a).

THE PATIENT WITH ISCHEMIC HEART DISEASE

The potential for using ratings of perceived exertion in cardiac rehabilitation is wide. Its simplicity is attractive, but its ease of administration may overextend its use.

Subjects who are at high risk will perceive exercise as being more difficult than physiological indications would lead us to believe (Borg, 1977a). We must make it simple and easy if we are to influence the cardiac patient to exercise. For those continuing on to an unsupervised exercise program, the RPE measure may be easy to use and will maintain confidence and decrease anxiety with exertion (Kavanagh &

Shephard, 1980).

Andrew, Oldridge, Parker, Cunningham, Rechnitzer, Jones, Buck, Kavanagh, Shephard, and Sutton (1981) found that the coronary heart diseased patient's perception of the exercise program was one of the three main categories associated with a high drop-out rate. Compliance with exercise programs is generally low (under 60%) (Shephard, 1985).

Some physiologists feel that the perceived exertion scale is appropriate for post-myocardial infarction, post-coronary artery bypass graft surgery, angina pectoris patients, and those on beta-blockade (Hage, 1981). Others feel RPE does not reveal cardiac insufficiency because it may be insensitive to dysrhythmias and ST segment changes, which may occur without symptoms at low levels of perceived effort (Hage, 1981). Perhaps cardiac patients should exercise only where electrocardiogram and cardio-pulmonary resuscitation facilities are available.

Ratings of perceived exertion could be used to allow subjects to choose a prefered work intensity. In a study of lumberjacks given their choice of level of activity, they chose levels at 50% of maximum. This coincides well with the stress an individual can endure for a lengthy period (Borg, 1971).

In patients who can withstand moderate workloads, RPE is suitable. Patients who work at very low workloads may interrupt the test for reasons other than intensity of load. Patients wih peripheral leg injuries will give quite different ratings from those with IHD (Borg, 1977a). Pain seems to raise RPE to considerably higher values, regardless of its source.

The rating of perceived exertion value can be used to interrupt training or testing if the work becomes too stressful. A set heart rate value of, for example, 130 beats per minute, may be too high for some patients (Kavanagh, 1985).

How does a sick person adapt to his or her illness? Various body sensations, together with experience as a frame of reference, are prime factors in determining behavior in any given situation (Borg, 1971). Of practical value would be studies of intermittent work which more closely simulate activites of daily life, or of repetitive work over long periods of time, such as an industrial work period.

OTHER CONCERNS

The verbal expressions of Borg's scale may pose a semantic problem. If the scale is translated into different languages the same linearity and high correlation is found betwen ratings and heart rate (Borg, 1977a). When a translation does not confirm this expected relationship the investigators should probably review the choice of verbal expressions for differences. The scale may not have the same meaning from patient to patient, but the researcher must assume that all categories are appraised similarly by all subjects. Reproducibility within the same patient is important (Borg, 1977a).

The rating of perceived exertion may be a dependent or an independent variable. It can be considered that the RPE variable is dependent on the basic physiological or psychological characteristics. But when a RPE is given to a subject who must exercise at that level, the RPE is an independent variable.

CHAPTER 3

METHODOLOGY

RESEARCH DESIGN

The experimental design for this study involved a two-factor repeated measurement on the same subjects under a number of various conditions: stationary cycling, treadmill walk/jogging, swimming, and volleyball. Consistency of the individual's RPE and heart rate was also studied.

SUBJECTS

Table 1 describes the subjects of this study. They were selected from among those with the following characteristics. They had incurred a cardiac event between October 1984 and September 1985, they participated in an established Phase III cardiac rehabilitation program, and they were not receiving beta-blockade medication. Twenty-three patients ranging in age from 37 to 65 years participated (7 females and 16 males). They were all victims of IHD in some form and degree, consisting of myocardial infarction, angioplasty, coronary artery bypass graft surgery, angina, or hypertension. Almost all would experience exercise-induced anginal pain if their hearts were overloaded beyond a certain rate pressure product.

INVESTIGATIVE PERIOD

The investigative period for this study was from September 23, 1985 to May 15, 1986.

TRAINING PROTOCOL

All subjects exercised three times weekly for one hour with various modalities. The exercise sessions were held

TABLE 1

CHARACTERISTICS OF SUBJECTS

SUBJECT	SEX	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)
1	Male	57	182	95.4
2	Male	55	177	80.9
3	Male	54	171	80.9
4	Male	56	173	75.0
5	Male	37	165	72.7
6	Male	57	177	78.1
7	Male	59	173	77.2
8	Male	54	175	83.1
9	Male	63	177	86.3
10	Male	65	175	74.5
11	Male	61	175	77.2
12	Male	62	174	79.5
13	Male	57	180	82.2
14	Male	53	168	69.0
15	Male	47	167	66.8
16	Male	62	174	65.0
MEAN	- MALE	56.1	173	71.8
S.D.[a]	- MALE	5.1	4.6	10.1
17	Female	53	157	59.0
18	Female	55	173	67.7
19	Female	56	155	49.0
20	Female	55	156	49.5
21	Female	60	160	56.8
22	Female	61	165	61.3
23	Female	59	163	50.0
MEAN	- FEMALE	57	161	51.9
S.D.	- FEMALE	2.7	5.8	7.8

[a]Standard Deviation

on Mondays, Wednesdays, and Fridays. At each of the three sessions, they were assigned to either a bicycle, treadmill, swimming, or volleyball program for that evening. Each area was supervised by an exercise specialist or physiotherapist, and each program was formatted in a standard manner to include approximately 15 minutes of warm-up exercises, 30 minutes of aerobic activity, a ten minute cool-down, and a five minute relaxation session (Appendix B).

Subjects had undergone a graded exercise stress test before commencing Phase III rehabilitation in order to evaluate progress in functional capacity and formulate an exercise prescription. The heart rate achieved at the end of the last completed stage of the Bruce protocol (1973) was used to calculate the training heart rate.

All patients had been given a target heart rate zone based on Karvonen's method of training heart rate prescription (Karvonen, Kentala, & Mustala, 1957).

TRAINING MODALITIES

The four training modalities studied were treadmill walk/jogging, stationary cycling, swimming, and volleyball. The training proram for each modality is described fully in Appendix B.

TESTING PROCEDURES

Each participant signed a consent form before taking part in the study (Appendix C).

At each exercise session during the investigative period, a data form was completed for each subject (Appendix D). The investigator recorded the date, type of activity performed by the subject, their resting heart rate, heart rate at peak aerobic activity, rating of perceived exertion at peak aerobic activity, recovery heart rate, and symptoms and comments.

Heart rate and RPE values were taken normally as an integral part of the training program. From the training records, an average of eight pairs of data per subject for each modality was used in this investigation.

HEART RATE

The carotid or radial pulse was monitored manually for ten seconds at the peak of the aerobic phase of activity, usually about 12 minutes after the stretching warm-up. Participants were well experienced in self-monitoring of heart rate but if they had trouble taking their pulse, they were assisted by the attending supervisor.

The subject was required to achieve a heart rate during training in his or her individual training zone or else the data was not used in this investigation.

RATING OF PERCEIVED EXERTION

The subjects rated their exertion level at the peak of the aerobic phase of training. Borg's RPE scale was used to obtain these values (Appendix A).

CRITERIA FOR CONSISTENCY OF RPE AND HEART RATE

An RPE value which described an exertion level within a heart rate of 12 beats per minute was considered within limits in terms of accuracy of manual heart rate palpation (Shephard et al., 1979).

The subjects provided a 10 second heart rate count, therefore an error of two counts per 10 seconds or 12 beats per minute could occur easily. An RPE value describing a heart rate range over 12 beats per minute and under 25 beats per minute was considered inconsistent. Anything over the range of 24 beats per minute was considered very inconsistent (Shephard et al., 1979).

ANALYSIS OF DATA

An observation of the individual's consistency of rating exertion with the various modalities was tabled. Also, a Pearson Product Moment Correlation was made between RPE and heart rate with modality.

For each subject, the average values of heart rate and RPE were calculated with each training modality. These values were then analysed with a two-way mixed model analysis of variance (ANOVA) for each dependent variable. The between subject factor was gender and the within subject factor was training modality (treadmill, cycle, swimming, and volleyball). Equally weighted analyses were conducted by running the SPSS MANOVA program (SPSS, 1983) version 2-0 with the METHOD=SSTYPE(UNIQUE) sub-command.

When a significant F-ratio was calculated, differences between means were tested for significance using Scheffé's critical difference test.

Further, to protect against violations of the sphericity assumption, the three step procedure recommended by Geisser and Greenhouse (1958) was used (for details see Kirk, 1982, pp. 252-262).

An alpha level of $p < .05$ was established as the level of significance for statistical testing.

CHAPTER 4

RESULTS

This study involved three areas of investigation. The first was a description of consistency of heart rate and RPE values given during exercise on four modalities. The second was a comparison of the correlation between both RPE and heart rate with modality, and the third was an analysis of variance (ANOVA) comparison of group tendencies and the effects of modality and gender on RPE and heart rate.

CONSISTENCY OF HEART RATE AND RPE

Tables 2 and 3 present the measured lower and upper heart rate values for each RPE value observed during training on all four modalities. For each subject, the lower and upper heart rate values experienced for each value of Borg's scale are given. In brackets next to the heart rate values is the number of observations of that heart rate range. The "overall" column gives the lower and upper values of heart rate for the four modalities of training combined for each value of Borg's scale, together with the sample size used to determine these values. For example, when Subject #1 rated his effort perception at 13, his heart rate value was between 120 and 144 beats per minutes over the entire set of 14 observations.

To describe their perceived exertion, most subjects tended to use the verbal descriptors at every odd number on Borg's scale (Borg, 1977b). Thus the numerical values tended to be odd numbers. A few subjects used the numerical scale and therefore their verbal reports included even numbers.

TABLE 2

HEART RATE LOWER AND UPPER LIMITS FOR EACH RPE VALUE ON FOUR MODALITIES

MEN

SUBJECT	RPE	ACTIVITY: TREADMILL	CYCLE	SWIMMING	VOLLEYBALL	OVERALL	CONSISTENCY
1.	11	-	-	-	120 (1)*	120 (1)	
	13	126 (1)	126-144(3)	120-144(6)	120-132(4)	120-144(14)	Inconsistent
	15	132-168(4)	144 (3)	144 (1)	-	132-168(8)	Very inconsistent
	17	-	144-150(2)	-	-	144-150(2)	Consistent
2.	11	-	-	84- 96(5)	84 (1)	84- 96(6)	Consistent
	13	84- 90(4)	82-102(7)	84- 96(3)	-	84- 90(14)	Consistent
	15	96 (1)	-	-	-	96 (1)	
3.	13	126-132(3)	126-150(2)	120-150(3)	132 (2)	120-150(10)	Very inconsistent
	15	126-138(4)	120-126(3)	120-132(3)	132 (1)	120-138(11)	Inconsistent
4.	11	114-120(2)	108-120(2)	108-120(4)	108-120(4)	108-120(12)	Consistent
	13	120-126(3)	114-126(4)	120 (2)	120 (1)	114-126(10)	Consistent
	15	126 (2)	120-132(4)	120 (1)	120 (2)	120-132(9)	Consistent
5.	9	-	-	-	120-126(2)	120-126(2)	Consistent
	10	-	-	-	120-138(3)	120-138(3)	Inconsistent
	11	138 (1)	144 (1)	126 (3)	120-126(3)	120-144(8)	Inconsistent
	12	126-132(2)	132-138(3)	138-144(2)	138 (1)	126-144(8)	Inconsistent
	13	150 (1)	-	-	-	150 (1)	
6.	11	-	-	-	120-126(2)	120-126(2)	Consistent
	13	126 (1)	132-128(3)	126-132(2)	126-132(3)	126-138(9)	Consistent
	15	126-144(2)	138-144(3)	-	-	126-144(5)	Inconsistent
7.	9	-	-	-	120 (1)	120 (1)	
	11	132-138(2)	120-132(2)	120 (1)	-	120-138(5)	Inconsistent
	13	138 (1)	132-144(5)	-	-	132-144(6)	Consistent
	15	-	144 (1)	-	-	144 (1)	

*The number in brackets indicates the number of observations of heart rates within that range.

..CONTINUED

TABLE 2

HEART RATE LOWER AND UPPER LIMITS FOR EACH RPE VALUE ON FOUR MODALITIES

MEN

SUBJECT	RPE	ACTIVITY				OVERALL	CONSISTENCY
		TREADMILL	CYCLE	SWIMMING	VOLLEYBALL		
8.	9	-	-	-	84- 90(3)*	84- 90(3)	Consistent
	11	96-102(2)	84- 90(4)	90- 96(6)	84- 96(4)	84-102(16)	Inconsistent
	13	96 (1)	-	-	-	96 (1)	
9.	11	96 (1)	90-102(3)	-	-	90-102(4)	Consistent
	13	-	96 (2)	92-102(4)	96 (1)	90-102(7)	Consistent
	15	-	102 (1)	-	-	102 (1)	
10.	11	-	-	120-132(4)	-	120-132(4)	Consistent
	13	132 (1)	120-126(2)	126-138(4)	120-126(2)	120-138(9)	Inconsistent
	15	138 (1)	132 (1)	-	-	132-138(2)	Consistent
11.	11	108 (1)	-	108-114(4)	114 (1)	108-114(6)	Consistent
	13	108-114(3)	108-114(3)	114 (2)	-	108-114(8)	Consistent
	15	-	114 (1)	-	-	114 (1)	
12.	11	78 (1)	-	-	72 (6)	72- 78(7)	Consistent
	13	84 (1)	78 (6)	78 (1)	72- 78(5)	72- 84(16)	Consistent
	15	102 (1)	84 (2)	84 (1)	84 (1)	84-102(5)	Inconsistent
13.	11	-	120 (1)	-	120-126(2)	120-126(3)	Consistent
	13	138 (1)	126-144(3)	126 (1)	120-126(2)	120-144(7)	Inconsistent
	15	120-126(2)	-	-	138 (1)	120-138(3)	Inconsistent
	17	138 (1)	-	-	-	138 (1)	
14.	11	114 (1)	-	-	114-120(4)	114-120(5)	Consistent
	13	114-120(3)	120-138(3)	114-126(4)	126 (2)	114-138(12)	Inconsistent

*The number in brackets indicates the number of observations of heart rates within that range.

..CONTINUED

TABLE 2

HEART RATE LOWER AND UPPER LIMITS FOR EACH RPE VALUE ON FOUR MODALITIES

MEN

		ACTIVITY					
SUBJECT	RPE	TREADMILL	CYCLE	SWIMMING	VOLLEYBALL	OVERALL	CONSISTENCY
15.	11	-	-	-	126-132(3)*	126-132(3)	Consistent
	13	-	-	132 (4)	138 (3)	132-138(4)	Consistent
	15	-	-	150 (1)	138-144(3)	138-150(4)	Consistent
	17	156-158(3)	150-174(5)	-	-	150-174(8)	Inconsistent
	19	156 (1)	-	-	-	156 (1)	
16.	9	114-120(2)	-	120 (1)	120 (2)	114-120(5)	Consistent
	11	120 (2)	120-132(3)	126 (2)	126 (1)	120-132(8)	Consistent
	13	126-132(2)	-	126 (1)	-	126-132(3)	Consistent

*The number in brackets indicates the number of observations of heart rates within that range.

TABLE 3

HEART RATE LOWER AND UPPER LIMITS FOR EACH RPE VALUE ON FOUR MODALITIES

WOMEN

SUBJECT	RPE	TREADMILL	CYCLE	SWIMMING	VOLLEYBALL	OVERALL	CONSISTENCY
17.	7	-	-	96 (1)*	96 (1)	96 (2)	Consistent
	9	-	108-126(3)	96-102(4)	96-102(2)	96-126(9)	Very Inconsistent
	11	96-114(5)	96-108(4)	96 (2)	96-102(3)	96-114(14)	Inconsistent
	13	108-114(3)	-	-	-	108-114(3)	Consistent
18.	11	-	120 (2)	120-132(2)	120-126(5)	120-132(9)	Consistent
	13	126-132(3)	-	126 (2)	120 (1)	120-132(6)	Consistent
	15	-	126 (1)	-	-	126 (1)	
19.	11	96 (1)	96 (1)	-	-	96 (2)	Consistent
	13	96-108(3)	96 (2)	102(1)	96 (1)	96-108(7)	Consistent
20.	11	120-126(2)	120-126(4)	120-126(5)	120-126(2)	120-126(13)	Consistent
	13	-	126 (1)	-	120 (1)	126 (2)	Consistent
21.	11	-	-	150 (1)	132 (1)	132-150(2)	Inconsistent
	13	138 (2)	132-138(5)	132-150(4)	138-144(2)	132-144(13)	Consistent
22.	9	-	-	-	72 (2)	72 (2)	Consistent
	11	72- 90(15)	72- 84(5)	72- 78(3)	72- 78(5)	72- 90(28)	Inconsistent
	13	72 (1)	-	72- 84(3)	-	72- 78(4)	Consistent
23.	11	114 (1)	108-120(2)	108-114(7)	108-114(7)	108-120(15)	Consistent
	13	120 (1)	108-126(3)	-	-	120-126(4)	Consistent
	15	120-126(4)	108 (1)	-	108 (1)	108-126(6)	Inconsistent

*The number in brackets indicates the number of observations of heart rates within that range.

Although heart rate was controlled within a limited safety zone approximating 60% of maximum heart rate reserve, the RPE values ranged from 7 (very, very light) to 19 (very, very hard) over all subjects. Most often the RPE values fell between 11 (fairly light) and 15 (hard) for men, and between 11 (fairly light) and 13 (somewhat hard) for women.

Tables 2 and 3 show that overall for both sexes, the IHD patients's peak exercise RPE value described a small heart rate range 66% of the time, whether treadmill walk/jogging, cycling, swimming, or playing volleyball. Men were consistent 27 times out of 42, or 64% of the time, and women were consistent 13 times out of 18, or 72% of the time.

An RPE corresponding to a particular heart rate range occured reliably 15 times for one woman and 16 times for one man.

Table 4 and Table 5 show the variation in means, standard deviations, and ranges for heart rate and RPE. Inconsistent RPE ratings between different individuals at the same heart rate on the same modality were seen. This is expected due to individual exercise capacities and various forms and degrees of IHD. Inconsistent heart rates between different individuals on the same modality at the same RPE value were also seen. The explanation for this is the same as above.

In some cases, such as Subject #5, ranges of heart rate values for a particular RPE value were wide for an individual over all four modalities, and within one modality.

TABLE 4

MEANS, STANDARD DEVIATIONS, AND RANGES

FOR HEART RATE ON FOUR MODALITIES

	MODALITY			
MEN	TREADMILL	CYCLE	SWIMMING	VOLLEYBALL
Mean	115.6	121.0	116.3	115.8
Standard Deviation	21.3	22.0	16.8	22.0
Range	85.5-145.2	79.8-144.0	81.5-129.5	75.6-132.0
WOMEN				
Mean	113.9	98.6	111.2	109.2
Standard Deviation	17.3	21.7	18.1	18.8
Range	82.8-138.0	82.2-134.4	82.8-138.0	78.0-138.0

TABLE 5

MEANS, STANDARD DEVIATIONS, AND RANGES

FOR RPE ON FOUR MODALITIES

	MODALITY			
MEN	TREADMILL	CYCLE	SWIMMING	VOLLEYBALL
Mean	13.5	13.3	12.5	11.9
Standard Deviation	1.6	1.3	0.9	1.2
Range	11.0-17.5	11.0-16.2	11.0-14.0	9.0-13.6
WOMEN				
Mean	11.9	12.3	11.7	11.1
Standard Deviation	1.0	0.9	1.2	1.2
Range	10.0-13.0	11.0-14.0	9.3-13.0	9.0-13.0

For some individuals, inconsistent RPE ratings between modalities were seen. For example, Subject #23 rated a treadmill walk/jog workout at an RPE of 11 when her heart rate was 114 beats per minute, but rated a volleyball workout at an RPE of 15 when her heart rate was 108 beats per minute. But overall, women were slightly more proficient at rating RPE according to actual heart rate measures than men were. It was noted that an RPE value was not always consistent at a given heart rate on different modalities, even for the same individual. For example, Subject #4 rated a treadmill walk/jog workout of 120 beats per minute at 13, and a volleyball workout of 120 beats per minute at 11. A scan of the data indicated that RPE values taken from these cardiac patients were not generally one-tenth of heart rate values.

In summary it can be concluded that, approximately two-thirds of the time, an individual is consistent and reliable using the RPE scale to measure their intensity of exercise.

COMPARISON OF THE CORRELATION BETWEEN BOTH RPE AND HEART RATE WITH MODALITY

Table 6 shows the correlation coefficients for heart rate and modality, and RPE and modality, for both sexes. Correlation coefficients between heart rate values on all modalities for both sexes were in all cases over r=.95,

TABLE 6

CORRELATION COEFFICIENTS FOR FOUR MODALITIES

	MEN			WOMEN		
MODALITY[a]	CY	SW	VB	CY	SW	VB
			HEART RATE			
TR	0.97*	0.95*	0.95*	0.99*	0.97*	0.98*
CY		0.96*	0.96*		0.95*	0.97*
SW			0.98*			0.99*
			RATING OF PERCEIVED EXERTION			
TR	0.90*	0.58*	0.67*	0.30	0.90*	0.81*
CY		0.71*	0.76*		0.02	0.52*
SW			0.80*			0.76*

[a]TR: Treadmill, CY: Cycle, SW: Swimming, VB: Volleyball.

*$p < .05$

indicating a very significant association between the values ($p < .05$). This relationship was confirmed as expected, given that the subjects were required to train within a controlled heart rate range.

The RPE correlations show a wider range. A significant association ($p < .05$) between RPE values on all modalities was observed for men. For women, lower correlations were seen overall, with an extremely low relationship between swimming and cycling ($r=0.02$) and a low relationship between cycling and treadmill ($r=0.30$).

EFFECTS OF MODALITY AND GENDER ON RPE AND HEART RATE

The ANOVA conducted on the heart rate data revealed a significant main effect for the training modality factor only, $F_{conservative}(1,21)=8.02$, $p < .05$ (Table 7). The Scheffé critical value was 12.33. The post-hoc tests indicated that the volleyball averages were significantly different from both treadmill averages (22.2, $p < .05$) and cycling averages (14.8, $p < .05$) (Table 8).

Box plots demonstrated that the median heart rate for women in all four modalities was lower than that of the men. This was also true for RPE values. Visual inspection of the data using stem-and-leaf diagrams (Tukey, 1977) did not suggest violation of the normality assumption.

The ANOVA table for the RPE data is shown in Table 9. Again, the analysis revealed a significant main effect for the training modality factor only, $F_{conservative}(1,21)=11.27$, $p < .05$. The critical Scheffé value was 12.33. These post-hoc tests were statistically significant between cycle and volleyball (34.5, $p < .05$) and between treadmill and volleyball

(23.3, $p<.05$) (Table 10).

The differences in both heart rate and RPE with modality are seen most clearly in volleyball as opposed to cycle and treadmill.

TABLE 7

HEART RATE

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	*F*
G (Gender)	913.97	1	913.97	0.60
Blocks w.G	3206.90	21	1527.10	
M (Modality)	408.45	3	136.15	8.03*
GM	43.05	3	14.35	0.85
M x Blocks w.G	1067.53	63	16.95	

*$p < .05$, ($F_{(1,21),.05}$) =8.02

TABLE 8

HEART RATE

SCHEFFÉ'S TEST STATISTIC

	Cycle	Swimming	Volleyball
Treadmill	1.6	10.3	22.2 *
Cycle		5.5	14.8 *
Swimming	–	–	2.3

$*p<.05$, $(F_{(1,21),.05}) = 12.33$

TABLE 9

RATING OF PERCEIVED EXERTION

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	df	MEAN SQUARE	*F*
G (Gender)	18.23	1	18.23	3.22
Blocks w.G	118.75	21	5.66	
M (Modality)	20.19	3	6.73	11.27*
GM	1.12	3	0.37	0.62
M x Blocks w.G	37.63	63	0.60	

*p<.05, ($F_{(1,21),.05}$) =8.02

TABLE 10

RATING OF PERCEIVED EXERTION

SCHEFFÉ'S TEST STATISTIC

	Cycle	Swimming	Volleyball
Treadmill	1.1	4.1	23.3 *
Cycle		9.4	34.5 *
Swimming			7.9

$*p < .05$, $(F_{(1,21),.05}) = 12.33$

CHAPTER 5

DISCUSSION

The principal reason for this investigation was to further clarify the use of RPE in cardiac rehabilitation, especially in its application in transfer of exercise prescription from one mode to another. A better understanding of the relationship between physical performance and effort perception is needed.

Inactivity is a modifiable risk factor in IHD (Hellerstein, 1984), therefore exercise should be an integral part of the rehabilitation program. A variable exercise program is less monotonous and more enjoyable than a repetitive program, therefore the use of RPE and several modalities could make exercise more appealing to the cardiac patient, and increase adherence (Kavanagh, 1985).

CONSISTENCY OF RPE RATINGS

Over all 23 subjects, the RPE was a close indicator of actual peak heart rate values in 14 subjects, or 60% of the time.

There is a basic relationship between heart rate and RPE in that an increase in one is seen with an increase in the other, and a decrease in one is seen with a decrease in the other (Borg, 1971). In the present study, RPE does not always covary directly with heart rate and the linear RPE-HR relationship is not always validated. RPE will continue to rise in steady state exercise despite a plateau in most other physiological variables (Noble, Metz, Pandolf, & Cafarelli, 1973). This confirms that heart rate and RPE are not causally related, since the same RPE value represented various heart rate values in different individuals. The converse was also true, the same heart rate elicited various RPE values depending on the individual.

The rating of perceived exertion can be considered to provide only a general indication of a heart rate range. Discrepancies in perceptual response as a function of exercise mode were also demonstrated by Sidney and Shephard (1977) who found that the treadmill evoked lower effort ratings at the same heart rate for the same subject than bicycle ergometer work.

The established training heart rate zones for these IHD patients had a range of 12-24 beats per minute, or 2-4 beats per 10 seconds. Therefore, 12-24 beats lie within the training heart rate zone. We were interested only in perception of exertion within the established training zone (60% of maximum aerobic capacity). Therefore, heart rates during exercise that did not fall within the individual's training zone were not considered in this investigation.

CORRELATION AND EFFECTS OF MODALITY ON RPE AND HEART RATE

A very significant relationship between heart rate and type of activity ($r=0.95$ and higher) was seen over all four modes for both men and women ($p<.05$). These correlations for heart rate were expected to be high due to the nature of the training prescription which controlled the heart rate within a narrow range. The rating of perceived exertion correlations were more variable and less strong. This can be explained considering individual disease states and psychological influences on effort perception. This also substantiates that heart rate is not the sole factor influencing RPE.

For women, the correlation coefficients between cycle and treadmill (r=0.30) and cycle and swimming (r=0.02) were very low. The lack of association between RPE responses on these modes is difficult to explain. Perhaps the level of intensity of exercise was too low to allow central factors to override external ones (Komi and Karppi, 1977). In this limited study of seven female subjects, thewomen were more inconsistent in their perception of effort.

A comparison of means provided information on the relative effect of the different modes of training on RPE and heart rate. Women, as demonstrated by lower average heart rates than men, tended to exercise at lower intensities. They perceived their exercise intensity to be lower as well.

Scheffé's test clarifies that a significant difference in heart rate exists between volleyball and cycling, and volleyball and treadmill. The volleyball matches apparently elicited significantly lower heart rates than treadmill walk/jogging or cycling. The subjects performed at the lower limit of their training heart rate zone, which is perceived as significantly more moderate than exertion at the higher limit. RPE values given for volleyball were also significantly different from those given during a cycling or treadmill workout. The fact that the differences in RPE and modality and heart rate and modality lie in the same factor provide evidence that heart rate and RPE are closely related. But it is possible to draw invalid inferences from the ANOVA if the data fails to satisfy the assumption that variances are homogenous (Ferguson, 1981). The normal, non-beta-blocked IHD patient may have a training heart rate in the wide range from 100 to 150 beats per minute.

INFLUENCE OF GENDER ON RPE

In contrast to the study by Arstila et al. (1977), reproducibility was high for perceived effort ratings independent of the sex of the subject. Both sexes were influenced in the same manner by the various modalities, and were equally able to describe their level of exertion on various modalities. It was noted that men were more able to rate effort in close correlation with their heart rate value than women. When compared to relative heart rate values as a percentage of maximum, women seemed to rate effort as less intense than men. This may reflect that they are working at a lower capacity. Therefore the rating of perceived exertion can be applied to IHD exercise programs for both sexes.

The sample group of this study was comprised of patients with various levels of fitness. Bar-Or (1972) and Mihevic (1983) found that fit and unfit subjects rate the effort required to perform standard workloads equally well. The results of this study confirm that the less fit cardiac patient can also be expected to be capable of accurate effort perception.

INFLUENCE OF EXERCISE MODE ON RPE

The influence of exercise mode on RPE is more complex, but must be clarified since most cardiac rehabilitation programs employ various modalities for dynamic exercise training. When intensity, frequency, and duration are relative, walking, jogging and cycling have been shown to be equally effective modes of cardiorespiratory conditioning

(Pollock et al., 1975). Walking and jogging are most readily employed in cardiac rehabilitation programs because they are easily regulated and accessible.

In this investigation, both treadmill and cycle elicited comparable heart rate and RPE responses. Volleyball elicited lower RPE ratings and heart rates at the lower end of the training zone.

During treadmill exercise, central factors seem to exert a greater influence on RPE (Pandolf, 1978). Efficiency is known to be greater for running than walking (Carton and Rhodes, 1985). This confirms that sensations originating in the working muscles are important determinants of RPE.

There are differences in sensory inputs between the two forms of exercise, running and cycling. Cycling, which utilizes relatively more high-glycolytic fast-twitch motor units, will cause a greater afferent input to the central nervous system from muscle spindles and Golgi tendon organs (Cain, 1971). It is known that for a given submaximal oxygen uptake, bicycle work will most likely elicit a higher lactate concentration than running, due to more pronounced static leg work on the bicycle. Therefore a higher RPE may be caused by a higher level of local muscular strain (Cain, 1971).

The subjects in this study exercised at 60% of maximum capacity, as recommended by Franklin et al. (1986) and Boone (1986), who feel that an exercise level of 40 - 60% of maximum can effect improvements in functional capacity. They feel that it is potentially harmful to use excessive intensities, duration and frequency of exercise for cardiac patients. Because exercise increases the risk of ventricular fibrillation up to 60 times (Shephard, 1977), exercise intensity is a hotly debated issue. Komi and Karppi (1977) found a low correlation coefficient for RPE and heart rate at exercise intensities below 50% of maximal heart rate values. Also, Mihevic and Morgan (1982) say local factors such as muscular strain exert the larger influence upon effort perception at exercise intensities which do not greatly stress central factors. In some programs there is a lack of close examination of the cardiac patient's exercise intensity, and exercise heart rate is not controlled as much as we would like to think (Boone, 1986). RPE is valuable in that it contributes an additional measure to the overall evaluation of exercise intensity. It can be used as a supplement to scientifically measurable variables. But Boone (1986) questions whether RPE can be assumed to be a sound basis for exercise prescription. Pandolf et al. (1978) stated that RPE values from Borg's scale may be valid only for protocols involving concentric exercise. But most activities, including cycling, biking, and swimming, are composed of both concentric and eccentric phases of movement.

The integration of local strain in the working muscles and central strain such as tachycardia and tachypnea is complex (Borg, 1977a). An RPE value taken at the peak of light, long duration work such as used in this study will be influenced by local neuromuscular, kinesthetic, and proprioceptive feedback from mechanoreceptors and chemoreceptors as well as tendon, skin, joint, and ligament receptors (Cain, 1971). Local components probably provide the most intense sensory stimulus, irrespective of the size of the muscle mass recruited (Pandolf & Noble, 1973).

Sensory cues are clearly functional at a moderate level of work. The subjects worked at a 60 rpm. At lower speeds, cycling requires slower muscular contractions and a smaller muscle mass, therefore the muscles are operating at a higher relative workload, and more effort is required (Pandolf and Noble, 1973). Effort perception may differ at equivalent power outputs when pedalling frequency is changed (Pandolf and Noble, 1973; Christensen and Ruhling, 1983). Again, standardization of protocol conditions must be employed for valid RPE research (Borg, 1977a).

With routine training, a lower RPE score for a given load should be seen due to cardiovascular gains and neuromuscular adjustments. Therefore, a training effect may have occurred over the eight month data collection period of the present study. For example, an individual may have rated his walk/jog workout as 15 (hard) in September, then at 11 (farily light) in April. This does not necessarily mean that the intensity of the workout was less vigorous, or that the reliability of the RPE value was questionable. Also, retesting may have increased or decreased the subject's sensitivity to RPE on various modes. Effects of previous treatments are not usually erasable. However, a minimal degree of previous exercise experience is necessary to gauge RPE accurately (Horstman et al., 1979). As the cardiac patient continued to exercise safely over a long period, anxiety levels may have decreased and even though the subject may have been exerting the same amount of physical effort as previously, their exertion level may be perceived to be lower. Further research into training related changes in RPE is necessary.

This study validates that RPE is as consistent in swimming as it is in cycling and treadmill exercise. Exercise of upper body musculature is an advantage of swimming and water games, and Samsoe (1984) suggests that water exercise be the recommended mode of training for cardiacs with concomittant problems such as arthritis or asthma. Swimming even at slow speeds can result in near maximal values for oxygen uptake and heart rates in myocardial infarction patients (Madger et al, 1981). Swimming pool walking is easily tolerable and of a moderate intensity, while incorporating both upper and lower extremities.

If the torso is ordinarily used in job performance, training of the arms, shoulders, and chest muscles through water exercise will give the IHD patient the confidence required to work without undue anxiousness. Since there is limited crossover effect between arm and leg training, swimming is an ideal activity for such patients. Few occupations require sustained jogging, while sustained arm work is common.

Physiological values such as ECG heart rates are difficult to measure in a pool setting. The use of RPE during water exercise could also be valuable from a safety point of view. Hypothermic conditions are a severe hazard for the exercising IHD patient. Heart rate and blood pressure fluctuations may occur when the water is cool, causing chilling on entry or subsequent discomfort. Caution must be taken in the pool setting if saunas and whirlpools are also present.

In this study, both RPE and heart rate values with swimming were similar to those elicited for the other three modes of training.

The perception of effort during volleyball is significantly different from that during treadmill walk/jogging or cycling. Volleyball is less well controlled and must be carefully supervised for consistency in exercise intensity. To achieve this, the participants can be encouraged to use both hands when contacting the ball, and to be "perceptually aware" of their exercise intensity falling too low.

Volleyball is well liked and it seems to elicit less anxiety for the cardiac patient than other competitive games. Modifications to the rules minimize skill requirements and make the game enjoyable for everyone. Inclusion of recreational games often enhances compliance (Franklin et al., 1984), probably due to the social aspect of games.

A special concern in cardiac exercise rehabilitation is upper body training. Since arm ergometry was not employed in this study we cannot infer the use of RPE on this modality. But RPE should be used with caution on an arm ergometer unless the prescription is based on blood lactate values, not heart rate (Ekblom and Goldbarg, 1971). They found that RPE values with arm work were lower for a given percentage of maximal oxygen uptake, probably due to the small muscle groups used in the exercise. A power output of 50% of that used for leg work is appropriate for arm training in healthy subjects (Franklin, 1986). A slightly lower maximum heart rate is obtained during arm rather than leg exercise testing in healthy subjects, therefore a prescription for arm exercise derived from leg exercise testing may be inappropriately high. Perhaps RPE could be a better measure for transfer of work intensity.

This study found a close relationship between perception of moderate exercise on both cycle and treadmill, in contrast to an investigation by Sidney and Shephard (1977) who noted somewhat lower RPEs on the treadmill as opposed to the cycle ergometer.

The present study confirms the statement by Kavanagh (1985) who says people have the ability to reproduce a similar level of exertion under various conditions. As demonstrated by Stamford (1976), the subject's ability to rate exertion does not change from one exercise mode to another with treadmill, cycle, or swimming at a moderate intensity of exercise. A small variation is seen in volleyball as opposed to cycling and treadmill walk/jogging.

DESIGN CONSIDERATIONS

This study necessarily addressed Borg's scale as applied to cardiac rehabilitation patients, not athletes. The twenty-three subjects gave a close approximation of a normal distribution of the IHD population (Ferguson, 1981), although they were not randomly chosen in a differential selection. It must be remembered that the inferential power of a study is governed by the procedure used in selecting the sample, given that all statistics are based on assumptions (Ferguson, 1981).

Due to the repeated measures design of this study, the measurements were highly correlated therefore reducing the error term. The same subjects were tested under a number of treatment conditions where the presentation of treatments was randomized to eliminate effects which might result from the order of the treatments. But carry-over effects such as fatigue, practice, boredom or any other circumstance may have occurred.

Jackson et al. (1981) says that the physiological and psychological correlates of exercise performance are different in a field setting as opposed to the lab. A large part of performance variance may be accounted for by motivation, which may be more or less present in a test setting. A formal lab setting may also have resulted in pressured or anxious respondents. Administration of the testing was simple, did not disturb the routine training session, and did not disrupt the exercising patient.

The values of Borg's scale given for exertion at a controlled heart rate range were wide, confirming the individuality of effort perception and the wide spectrum of IHD physical manifestations. Each patient with IHD is an individual case made up of a varied history of risk factors and related health problems (Hall, 1984). Also, the psychophysiological nature of perceived exertion warrants a serious consideration of the individual as well as group tendencies (Morgan, 1973). A study analyzing the characteristics of a group of subjects will not clearly reveal individual differences. For these reasons, both individual and group tendencies were examined in this study.

For most individuals, there are approximately five pairs of data per modality. This is an average of 20 observations per subject, a large amount for studies of individual tendencies. For a few individuals, only one pair of data for a particular mode was available. Too much data may confound results, and a larger, more complex analysis is not always more informative (Ferguson, 1981). Instrumentation of data collection may have jeopardized these results. Due to the use of a ten second manual heart rate measure, a loss of accuracy of only one beat within this period calculates to six beats per minute on either side of the actual heart rate measure. Inaccuracies if they occurred probably resulted most often from an uncounted beat, leading to an underestimation of the actual heart rate. This problem predictably occurs most frequently with treadmill or cycle ergometer counts, where the noise of nearby rhythmic equipment may interfere with proper counting. Also, the time taken to locate and begin counting the pulse may be long enough to cause a significant decrease in the true measure (Froelicher, 1983). Shephard et al. (1979) found a small range of error (less than 8 bpm) for people with a modest experience in pulse counting, with even greater precision during exercise.

The researcher made two critical assumptions that may have had an influence on observed results. One, it was assumed that the subject was exercising at 60% of maximum. If the subject was not, we are inferring the value of RPE at this moderate level of activity in error. Two, it was assumed that the training heart rate from the subject's most recent stress test was accurately derived. This limitation is inherent in all exercise prescriptions based on the Bruce protocol stress test (Bruce, Kusumi, & Hosmer, 1973). Karvonen's method, which was used to calculate a training heart rate from heart rate reserve, may overestimate the desired aerobic training intensity in early cardiac rehabilitation since it fails to correct for the non-linear heart/oxygen uptake relationship in IHD (Dressendorfer and Smith, 1984). Occupational work demanding an oxygen uptake similar to that achieved during leg exercise testing does not necessarily produce the same cardiac demands. But ACSM (1986) states that similar RPEs are obtained at a given percentage of heart rate reserve regardless of peak heart rate or beta-blockade dosage.

PSYCHOLOGICAL INFLUENCES

A simple collection of heart rate and RPE data does not provide a complete understanding of effort perception. RPE is most likely greatly effected by a number of extraneous psychological factors. These would exert a larger influence on RPE at low intensities than at higher workloads, when physiological cues are intense.

The external validity of this design may have been jeopardized by these uncontrollable factors. Events occuring between measurements, such as sleeplessness, could have effected a person's RPE. Pain threshold, individual sensory awareness, experience on the activity, nutritional status, and overall physical conditioning may have influenced the individual's performance and their estimate of effort expenditure.

Motivation, energy level, and general attitude may explain poor performance or poor adherence to an exercise task. Morgan (1973) says physiological variables account for only 67% of the total variance in RPE. Therefore an assessment of motivational state and traits would be valuable in this study. A short questionnaire given before the exercise session would reveal possible daily fluctuations in mood, energy level, tiredness, and stress. Psychomotor and mental performance tasks including effort perception are also affected by the time of day. To control for this, data used in this study was collected at exercise sessions conducted at the same time each day.

This study of 23 IHD patients included some extroverts, who have a higher pain tolerance than introverts (Morgan, 1973). Other factors confusing the issue are the over-anxious patient who might develop a psychological dependence on electrical heart rate monitoring and who may be reluctant to use RPE because it is not "scientific". Or the competitive subject may recall that RPE should match or be lower than previous workout values therefore make a conscious effort to provide the expected responses, regardless of actual physical sensations.

USE OF RPE

It can be stated that RPE can be used for monitoring exercise intensity when a patient transfers from one exercise modality to another. The rating of perceived exertion can, therefore, be used to make relative comparisons between exertion from one day to the next or from one progressive stage of training to the next. But it cannot be used indiscriminately for all cardiac rehabilitation patients. Kavanagh (1985) cautions against the use of RPE by those who are "deniers", who consistently overestimate their physical ability. For those prone to ventricular arrhythmias, whose strict adherence to target heart rate is essential, the use of RPE may result in dangerously high heart rates (Smutok et al., 1980). Perceived exertion does not allow for detection of dysrhythmias and ischemic ST-segment displacement which can occur without symptoms during exercise. Fardy et al. (1982) found 10 of 70 patients had potentially life-threatening cardiac abnormalities but did not experience any untoward symptoms with exercise. There is a serious danger of relying solely on subjective estimation of effort since patients may not be aware that serious problems can occur even during light exercise.

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The influence of gender and training mode (treadmill, cycle, swimming and volleyball) on Borg's Rating of Perceived Exertion and heart rate was investigated in a Phase III cardiac rehabilitation program. Twenty-three patients with IHD participated for eight months in a triweekly 60 minute exercise session where RPE and heart rate were monitored at peak activity. The results indicated that both male and female IHD patients have equal ability to perceived effort. A significant difference ($p > .05$) was found in the influence of training mode on both RPE and heart rate in the case of volleyball, although the subjects were required to train on all four modes within a narrow heart rate range. An analysis of individual trends showed that certain subjects were able to rate RPE consistently with heart rate over all four modes, while others were not. Overall, the subjects were consistent at rating RPE within a narrow heart rate range (12 beats per minute) 66% of the time. These findings reveal that RPE is a valid general indicator of work intensity on various modes. It is recommended that the RPE scale be used with caution for IHD patients requiring strict monitoring of exercise intensity, and that it be used for intraindividual comparisons only.

CONCLUSIONS

Cardiac rehabilitation is still in its formative years, and the effort perception is more of an art than a science (Boone, 1986). This investigation has contributed further to the understanding of the application of RPE in cardiac rehabilitation exercise programs.

1. It can be concluded that RPE is an acceptable, but not definite assessment tool as an indicator of the subject's exertion level in cardiac rehabilitation.
2. The strength of association between RPE and modality is greatly affected by individual variances.
3. The rating of perceived exertion should be used with reservation in monitoring the intensity of the IHD patient's exercise program.
4. The use of RPE as an intensity guideline in transfer from one exercise mode to another may not necessarily reflect physiological values such as heart rate. This does not preclude the value of this measure in that the patient's perception of the "sensation" of exercise is what is important.
5. The validity of these conclusions may be dependent on the extent and degree of extraneous factors affecting the sample's ability to rate their perceived exertion.

RECOMMENDATIONS

The use of RPE in cardiac rehabilitation requires continued study. Many inconsistencies must be resolved for future investigations.

1. Stress tests should be carried out at regular three month intervals, with necessary adjustments to the exercise prescription made according to changes in fitness level, medication, and lifestyle.
2. Rigorous standardized training procedures with ECG or telemetric monitoring of heart rate should be employed

for valid interpretation of data.

3. A large percentage of cardiac patients receive daily beta-blockade medication, and the interaction of these two common treatment modalities for IHD, beta-blockade and exercise, needs to be further elucidated.
4. The application of RPE to those on calcium channel blocker medication, or for those who have left ventricular dysfunction or a fixed heart rate pacemaker should be further clarified.
5. Of interest would be a study of the same participants looking at effort perception and RPE variation during exercise at various levels of intensity. Would the subject's ability to rate effort differ at more moderate or more vigorous levels?
6. A logical extension to this study would be to investigate changes in RPE over the duration of a training period. How much variation in RPE must be seen to conclude that a training effect has occured?
7. Further investigation is needed before RPE can be applied to exercise prescription or before cardiac patients are encouraged to regulate exercise training solely by perception of effort.

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APPENDICES

APPENDIX A

PERCEIVED EXERTION SCALE

15 POINT RATING

(Borg, 1977b)

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 B

TYPICAL TRAINING SESSION

WARM-UP PHASE (10 - 15 minutes)

The warm-up served the purpose of preparing the system for further physical stress. The typical session included stretching exercises for all large muscle groups of the body. A background of music was used for the warm-up and cool-down phases.

Resting heart rate was taken and recorded before commencing. Slow, static, full range-of-motion stretches through the neck, shoulder, elbow, wrist, torso, hip, knee, and ankle joints were performed for 10 minutes. A few minutes of stationary aerobic work, including leg lifts and leg kicks, were performed to increase the heart rates into the training zones.

AEROBIC PHASE (30 - 40 minutes)

This period consisted of individual training sessions for each participant, based on their exercise prescription from their most recent stress test evaluation. The patient could choose a bicycle, treadmill, volleyball, or swimming exercise workout. The patients were encourged to vary the training modality at each tri-weekly session.

Training heart rates were determined using Karvonen's method (training heart rate equals resting heart rate plus 60% of maximal heart rate minus resting heart rate) (Karvonen, Kentala, & Mustala, 1957). Maximal heart rate values were obtained from the patient's heart rate value at the last completed stage of the Bruce protocol (1973) on the treadmill stress test. The training zone was considered to be from six beats per minute below to six beats per minute above the value calculated from Karvonen's formula (1957).

The patient would manually monitor their own resting heart rate, peak heart rate, and recovery heart rate, with assistance from the attendant if necessary. They would note this data on a data sheet (Appendix D), together with a rating of perceived exertion at peak exercise intensity.

If the pulse count fell above or below the training prescription zone, or if symptoms of discomfort were felt, the prescription would be temporarily modified by the attendant as required.

TREADMILL PROGRAM

Roller-driven Landice treadmills were used for about thirty minutes, and were controlled by the participant at a pace that elicited his or her training heart rate. Radial or carotid pulses were monitored frequently by the attendant or participant.

CYCLING PROGRAM

Subjects spent about 30 minutes on the Fitron cycle ergometer. They pedalled at 50 rpm at a tension which elicited a heart rate in the training zone. The radial or carotid pulse was monitored often by attendent or participant, with modifications in tension made if necessary.

VOLLEYBALL PROGRAM

The volleyball activity took place in a separate gymnasium with full equipment. The game was modified to allow the ball to be in almost continuous motion, and to encourage participants to be more active. Six or seven players were on the court at once, and rotations occurred with each change of server. Substitutes were not made so all participants were continually active. Scores were not kept and rules were adjusted to allow three consecutive serves per player, the ball could bounce on the floor, and three hits were to be made on each side before returning the ball over the net. The game lasted thirty minutes. Breaks were interspersed periodically between plays for heart rate counts and RPE monitoring.

SWIMMING PROGRAM

The pool program consisted of 30 minutes of water activity, including stationary aerobic work, walking or jogging in the water, team or paired relays, dances, and free swimming. Modified polo or water volleyball games were included but participants were discouraged from competitive behavior. If the games got too rowdy they were discontinued at that session and a less vigorous water activity was substituted. The group was instructed to take heart rate counts every five minutes and RPE was checked at the time of peak activity.

COOL-DOWN PHASE

Abdominal and lower back exercises were included in this phase. Then the stretches were repeated in a relaxed manner for about 10 minutes until heart rates had dropped to pre-exercise values. A few minutes were spent in relaxation to music, practicing deep breathing, and progressive muscular relaxation exercises.

APPENDIX C

CONSENT FORM

I, ... ,
understand that Lakehead University is undertaking a study to investigate the variability of heart rate and rating of perceived exertion on different exercise modalities. I realize that this information will be collected from me at each exercise session.

I understand that I will remain anonymous and that any personal data collected will be kept confidential. I further consent to the use of information obtained by the investigator.

As a cardiac patient, I am aware of the potential risks involved with exercise and exercise testing, and give my permission as a participant in this study. In agreeing to be a participant, I accept all responsibility and waive any legal resource against the investigator from any and all claims resulting from personal injury incurred during the period of this investigation.

DATE: ....

SIGNATURE: ....

WITNESS: ....

APPENDIX D

DATA FORM

NAME .... AGE .....

MEDICATIONS ....

EXERCISE PRESCRIPTION

Training Heart Rate Zone ....

Bike ....

Treadmill ....

DATE	MODALITY	RESTING HR	PEAK HR	RPE	RECOVERY HR	COMMENTS

APPENDIX E

RAW DATA FOR HEART RATE ON FOUR MODALITIES

SUBJECT	SEX	MODALITY TREADMILL	CYCLE	SWIMMING	VOLLEYBALL
1	Male	145.2[a]	144.0	130.2	126.0
2	Male	88.8	88.8	88.8	84.0
3	Male	132.0	130.8	129.0	132.0
4	Male	120.6	121.8	120.0	115.2
5	Male	136.8	138.0	132.0	124.8
6	Male	132.0	138.0	129.5	129.5
7	Male	133.8	138.0	120.0	125.4
8	Male	97.8	85.8	91.2	87.5
9	Male	96.0	96.0	96.0	96.0
10	Male	135.5	126.0	127.8	123.5
11	Male	109.8	111.6	110.4	114.0
12	Male	85.5	79.8	81.5	75.6
13	Male	130.8	132.0	126.0	126.0
14	Male	117.5	126.0	118.8	117.5
15	Male	160.8	158.4	136.8	141.5
16	Male	123.5	121.8	123.0	122.8
17	Female	107.4	109.8	96.6	97.8
18	Female	127.8	123.6	127.8	122.4
19	Female	99.6	96.0	99.6	96.0
20	Female	123.5	126.0	123.5	123.6
21	Female	138.0	134.4	138.0	138.0
22	Female	82.8	82.2	82.8	78.0
23	Female	118.0	114.6	110.4	108.6

[a]Average of heart rate values on that modality over the investigative period.

APPENDIX F

RAW DATA FOR RATING OF PERCEIVED EXERTION ON FOUR MODALITIES

SUBJECT	SEX	MODALITY TREADMILL	CYCLE	SWIMMING	VOLLEYBALL
1	Male	14.6[a]	15.0	13.2	13.0
2	Male	13.4	13.0	11.8	13.0
3	Male	14.0	14.2	14.0	13.6
4	Male	13.3	13.3	13.3	12.2
5	Male	12.0	11.8	11.6	10.3
6	Male	14.3	14.3	13.0	13.0
7	Male	12.3	13.0	11.0	9.0
8	Male	11.6	11.0	11.0	10.6
9	Male	11.0	13.0	13.0	13.0
10	Male	14.0	13.6	12.0	13.0
11	Male	12.5	13.4	12.4	11.1
12	Male	13.0	13.0	14.0	11.5
13	Male	15.0	15.0	13.0	12.6
14	Male	12.5	13.0	13.0	12.0
15	Male	17.5	16.2	13.8	13.8
16	Male	11.0	11.0	11.0	9.6
17	Female	10.0	11.8	9.3	9.6
18	Female	12.3	13.0	12.0	11.4
19	Female	12.3	12.3	13.0	13.0
20	Female	13.0	11.0	13.0	11.3
21	Female	13.0	13.0	12.6	12.3
22	Female	10.8	11.1	11.0	9.0
23	Female	12.1	14.0	11.1	11.6

[a]Average of perceived exertion values on that modality over the investigative period.