ABSTRACT

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Twenty-six volunteers, ages 19-36 years completed 3 exercise tests (females = 22; males = 4). The purpose of the study was to evaluate the use of rating of perceived exertion (RPE) as a frame of reference for the production of a range of walking and running intensities. Submaximal RPE calibration tests were conducted establishing 2 RPE levels (10 & 12.7) on the basis of two HR ranges (115-125 bpm; 145-155 bpm). The initial submax test was followed by a VO_2max test. Ss were randomly assigned to replicate the 2 RPE levels on the treadmill and track. Means and standard deviations for physical characteristics and max exercise data (VE=108.1 $ml \cdot min^{-1}$, VO_2= 3.1 $l \cdot min^{-1}$; VO_2=46.7 $ml \cdot kg^{-1} \cdot min^{-1}$; RER=1.2; HR=191.2 bpm; RPE=18.2) were computed for all Ss. A 2 x 3 ANOVA was computed to determine if there was a sig diff among tests. By design the low RPE resulted in sig ($p<.05$) lower HR response than the moderate RPE. No sig ($p<.05$) was shown in HR responses between the initial test and the treadmill test. The HR response to track walking and running was sig ($p<.05$) higher than the initial and treadmill tests. These results indicated that Ss underestimated exercise intensities in relation to HR values in the track setting. No sig ($p<.05$) interaction occurred among the factors of RPE level and exercise setting. The results of this study indicated that the Ss were less accurate replicating RPE values in an uncontrolled or track setting vs the controlled or treadmill setting. From these results it is apparent that RPE cannot be the sole means of monitoring exercise intensity in an uncontrolled or field setting.

A COMPARISON OF RATING OF PERCEIVED EXERTION IN TREADMILL VS TRACK WALKING AND RUNNING

A Thesis Presented

to

The Graduate Faculty

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In Partial Fulfillment

of the Requirements for the

Master of Science Degree

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by

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DEDICATIONS

This thesis is dedicated to those who provide the foundation for my accomplishments:

To my family, who have always supported my many endeavors and believed in me when I lost faith in myself.

To my friends and classmates, thank you for your support and countless wonderful memories.

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CHAPTER I

INTRODUCTION

The application of rating of perceived exertion (RPE) has become widespread in the area of clinical exercise testing. It is currently believed that the use of objective measurements including heart rate, oxygen consumption, minute ventilation volume, and blood lactate accurately assess physiological parameters during exercise, but fail to evaluate subjective responses (Eston, Davies, & Williams, 1987). Through the use of a subjective rating of effort scale originally devised by Borg (1973), collection of subjective measurements as a supplementation to objective data during exercise testing has been researched. Through continual research, a relationship between physiological and psychophysiological parameters has been determined. Rating of perceived exertion has been found to be significantly correlated [r = 0.75 - 0.90] (Borg & Linderholm, 1967; Frankenhaeuser, Post, Nordheden, & Sjoeberg, 1969; Skinner, Borg, & Buskirk, 1969; Borg, 1973) with heart rate and appeared to be most closely related to a proportion of maximal capacity at a given workload (Morgan, 1973).

From this information it was determined that RPE plays a role in exercise testing, however investigators (Smutok, Skrinar, & Pandolf, 1980; Eston & Williams, 1988) have questioned the extent to which RPE can be utilized. Some researchers believe that the subjective measure

of RPE must be explored in terms of production of specific intensity levels as the result of practice or tr' 'ning at these specific levels. Borg and Noble (1974) stated "the perception of exertion is a perceptual cue of value for the regulation of proper work intensities (p. 150)". Morgan (1981) stated:

> ..many fundamental questions in the area of perceived exertion need to be answered, numerous applications in the exercise and sport sciences are readily apparent ... it is time to move inward, catch the signs and adopt effort sense strategies- in short, focus on the psychophysiology of self-awareness during vigorous physical activity (p. 426).

Eston et al. (1987) and Smutok et al. (1980) have substantiated that the achievement of accurate effort production from RPE is reasonably accurate at higher levels of RPE, but is less accurate at lower RPE levels. Eston et al. (1987) also stated that through practice sessions the accurate production of effort at lower RPE levels can be obtained. This study attempted to verify the theory that the RPE can be applied to exercise practice sessions. In addition, it attempted to determine if the production of effort over a range of intensities can be acquired and precisely replicated at specific exercise intensities.

Purpose of the Study

The purpose of this study was to evaluate the use of rating of perceived exertion (RPE) as frame of reference for the production of a range of walking and running intensities by young men and women. This study attempted to determine the application of RPE to control intensity of work, in addition to determining the relationship between perceived effort and the ability to reproduce effort at various levels previously experienced.

Need for the Study

The need for this study is based upon the insufficient evidence concerning the precise relationship between perceived effort during exercise training and the production of effort at a level equivalent to a previously experienced intensity. The utility of determining the relationship between perceived effort and the production of perceived effort at specific intensities lies in the area of exercise training programs. Eston et al. (1987) stated:

> A potentially useful variant of this application of RPE would be for an exercising person to use or, if necessary, 'learn to use', an appropriate version of the scale to control the intensity of work, for example during training for endurance in athletics. This would obviate constant reference to complex laboratory facilities (p. 222).

Eston et al. (1987) indicated that the utilization of RPE as a prescriptive or regulatory device has yet to be proven valid. Therefore, it is necessary to determine the extent to which the application of RPE can be utilized.

Smutok et al. (1980) demonstrated that the use of RPE for active adult men is reliable at heart rate values exceeding 150 beats per minute or 80% of heart rate maximum and running speeds of 9 km per hour. Purvis and Cureton (1981) reinforced the results of Smutok et al (1980) by determining the achievement of accurate effort production from RPE was reasonably accurate at higher levels of RPE (13 and 17), but less accurate at its lowest level. From these studies it is apparent that the production of effort at lower RPE intensities, based on previously experienced lower levels of exercise, has low reproducibility during training sessions. Consequently, this study attempted to evaluate the

application of RPE in modifying variables including exercise intensity and exercise modality. Subjects were evaluated on their ability to produce specific exercise intensities following the completion of a practice period.

Null Hypothesis

The following null hypothesis was formulated for this study and tested at the .05 level of confidence:

There is no significant difference in HR responses when utilizing specific levels of intensity on the RPE scale during track and treadmill exercise.

Assumptions

The following assumptions were made in this study.

1) The subjects were normal, healthy individuals who based their exercise intensity levels upon subjective perceived exertion levels.

2) All subjects performed maximally during the maximal treadmill test.

3) The subjects had no previous experience with the Borg (1973) rating of perceived exertion scale.

4) All subjects understood directions for Rating of Perceived Exertion (Borg, 1973).

Delimitations

The delimitation of the study was that the subjects were selected from the thirty students enrolled in the Physical Therapy Program at University of Wisconsin-LaCrosse.

Limitations

The limitations of the study were:

1) The twenty-six subjects were not randomly selected.

2) The researcher had no control over individual characteristics such as, personality traits, motivation, learning effects, and physical fitness level.

Definition of Terms

Borg's Rating of Perceived Exertion Scale. A scale of perceived exertion which enables individuals to subjectively rate their own degree of fatigue or stress. The Borg scale ranges from 6-20 (Borg, 1973).

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

Central Factors. These factors are sensations or feelings from the cardiopulmonary system (Pandolf, 1982) and include measures of ventilatory minute volume (VE), respiration rate (RR), heart rate (HR), and oxygen consumption (VO_2) (Mihevic, 1981).

Local Factors. These factors refer to feelings of strain in exercising muscles. Parameters that may provide sensory input for perceived exertion are: 1) muscle lactate; 2) Golgi tendon activity; and 3)

general muscle sensations (Mihevic, 1981).

Maximal Oxygen Consumption. The maximal amount of oxygen an individual can take in, transport, and use per minute during maximal effort during a treadmill test. The VO_2max criteria included a plateau or leveling off of VO_2 (< 150 $l \cdot min^{-1}$) with increasing workload and a respiratory exchange ratio greater than unity (> 1.0).

Rating of Perceived Exertion. This is an individual's subjective rating of the intensity of work being performed (Morgan, 1973). The overall perception of exertion may be regarded as a gestalt of many sensations and feelings related to the work requirement (Borg & Noble, 1974). This was determined using Borg's 15 point scale.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Over the past decades ratings of perceived exertion (RPE) have played increasingly greater roles in exercise physiology studies. In 1986 Borg and Ottoson stated "...an important trend in physiological assessment in recent years has been the tendency to collect how people feel while engaged in physical work, to augment usual measures of physiological response" (p. 180). Such ratings are important complements to behavioral and physiological measurements of physical performance. The process of determining effort sense or RPE results from a complex interaction of cognitive and metabolic processes (Borg, 1973). Theoretically Borg believed that it should be possible to explain the psychophysical function based upon different physiological functions.

In 1970 Borg devised a 15 point scale based upon a correlation between perceived exertion and heart rate. Borg designed his 15 point RPE scale to be parallel to the linear increase in heart rate (HR) which results as exercise intensity rises. A given perceptual rating can be multiplied by a factor of 10 to approximate the exercise HR. Results of various studies have suggested that HR does not provide strong central signals to the perception of effort, yet a linear relationship between

RPE and HR exists (Noble, Metz, Pandolf, Bell, Cafarelli, & Sime, 1973; Pandolf, 1977). The Borg scale displays a relationship between HR and RPE with correlations between 0.80-0.90 computed over a wide range of workloads (Borg & Noble, 1974). Inter-individual comparisons can be determined with the scale and RPE values can be used to reflect physiological strain while exercising.

Other studies have also displayed a strong linear relationship between these two variables for both male and female subjects (Skinner et al., 1969; Skinner, Hutsler, Bergsteinova, & Buskirk, 1973; Stamford, 1976) of varying fitness levels (Skinner et al., 1973). The linear relationship also remains consistent over various training modes (Borg, 1973; Skinner et al., 1973) during intermittent or continuous exercise (Edwards, Melcher, Hesser, Wigertz, & Ekelund, 1972).

In 1971, Ekblom and Goldbarg suggested that the perception of effort during exercise was based upon two categories of factors. The first category represents local factors or feelings of strain in exercising muscles and/or joints. Central factors or feelings associated with primarily the cardiopulmonary system represented the second categorical factor. This two factor model served to be an extension of Borg's original proposal which stated that during short-term work perceptions of exertion emanate in the skin, muscles, and joints. During long-term work sensations from the organs of circulation and respiration are important in terms of perception of exertion (Borg, 1973).

Researchers have determined that local factors are assumed to provide the primary sensory signals. In turn, central factors act as

amplifiers that potentiate the local signals in proportion to metabolic demand (Cafarelli & Noble, 1977; Robertson, 1982). Robertson (1982) determined that during the first 30 seconds of dynamic exercise exertional sensations are solely local in origin. Central factors begin their potentiating roles approximately 30-80 seconds after the initiation of exercise, which corresponds to the time period required for cardiovascular and ventilatory adaptation. Robertson (1982) also determined that local signals dominate the perception of effort at all exercise intensities while ventilatory or central cues become more pronounced at higher exercise intensities.

In the attempt to explain the psychophysical function of individuals during work performance, researchers have studied various measurable physiological functions which are categorized as central factors (Borg, 1973; Noble, Metz, Pandolf, & Cafarelli, 1973; Pandolf, 1977; Pandolf, 1978; Mihevic, 1981). This chapter reviews literature in the following areas: (1) physiological factors related to RPE, (2) reliability and validity of perceptual responses, (3) perception of effort during aerobic exercise and, (4) individual difference variables which may influence ratings of perceived exertion.

RPE and Ventilatory Function

Research has supported the role of minute ventilation (VE) and/or respiratory rate (RR) as sensory cues which influence the perception of effort (Carton & Rhodes, 1985). Correlation coefficients ranging from 0.52 to 0.94 have been determined between RPE and both VE and RR (Edwards et al., 1972; Noble, Metz, Pandolf, & Cafarelli, 1973; Pandolf,

Cafarelli, Noble, & Metz, 1972; Sargeant & Davies, 1973; Skinner et al., 1969; Smutok et al., 1980). The actual strength of the ventilatory signal may depend on the metabolic intensity achieved during physical performance. Edwards et al. (1972) found that the intensity of the ventilatory signal increases as the metabolic rate increases. Noble, Metz, Pandolf, & Cafarelli (1973) determined VE and RR to be the best predictors of RPE, when studied in either a hot or neutral environment. While Edwards et al. (1972) stated that VE has afferent nervous system input that can be monitored consciously.

RPE and Metabolic Demand

Correlations between 0.76 to 0.97 have been noted between VO_2 and RPE (Edwards et al., 1972; Sargeant & Davies, 1973; Smutok et al., 1980). Researchers have demonstrated that while VO_2 increases with respect to workload, RPE also increases according to a positively accelerating function which closely approximates VE and blood lactate curves (Borg & Noble, 1974; Mihevic, 1981). Sargeant and Davies (1973) stated that it is the relative and not the absolute VO_2 that plays a critical role in determining the perception of exertion during dynamic exercise. Astrand and Rodahl (1977) found that when comparing exercise at equivalent relative exercise intensities, VO_2 fails to account for physiological responses which may differ between individuals. Therefore, they found it more reasonable to state that VO_2 is indirectly related to RPE due to the input of certain physiological parameters such as VE and blood lactate that are linked to relative metabolic demand.

Reliability and Validity of Perceptual Responses

After the development of Borg's 15 point RPE scale extensive research was undertaken to test the reliability and validity of perceptual responses. In 1972, Michael and Eckhardt exercised six male subjects for 15 minutes on a treadmill at a work intensity considered "hard" at 0% slope. Later subjects were asked to reproduce an equivalent level of work at a slope of 10%. The results of this study revealed no significant difference between the exercise intensities using the two different protocols. This demonstrated reliability of RPE despite variations in protocols. Skinner et al. (1973) studied the question of whether subjects could perceive small differences in work intensity if workloads were presented in a random order under two training protocols: continuous and isolated. They found no significant differences in any of the physiological and perceptual variables between the two types of test protocols. Stamford (1976) agreed with Michael and Eckhardt (1972) when he determined that RPE readings were reliable and valid, and independent of exercise intensities. The RPE values which were collected proved to be reproducible ($r = 0.76$) during intense (>90% VO_2max) and less severe exercise.

Ulmer, Janz, and Lollgen (1977) raised doubts about the validity of the Borg scale due to the fact that it is based upon the correlation between HR and perceived exertion. Their research on well-trained athletes indicated that RPE is more highly correlated with what they consider to be the stress (workload) of exercise rather than the strain (heart rate).

In relation to running, exercise prescriptions based upon the RPE scale provide a safe and reliable HR response above 80% HR maximum or at RPE 12 and above (Smutok et al., 1980). It is noteworthy that the correlations between RPE and HR were lower at all levels of the analysis than those that accounted for the correlations between RPE and VO_2, leaving some 40% of the variance unaccounted for overall. The reason for the large amount of variance between RPE and HR may be due to the fact that HR is known to fluctuate on an intra- and inter- subject basis as a result of environmental and emotional influences (Eston & Williams, 1988).

Recently Eston and Williams (1988) concluded that RPE is a useful frame of reference for the regulation of high levels of exercise in healthy men and women. With small amounts of practice using the RPE scale, subjects can improve its applicability at lower exercise intensities. Their results demonstrated a trend towards greater reliability both as the work becomes more intense and with more experience on the task with the exception of high levels of intensity. At higher levels relating to a RPE value of 17, between-trial correlations for VO_2 were consistently high ($r = 0.92$ or greater).

Perception of effort cannot be solely based upon physiological input alone. The performance of muscular exercise depends to some degree upon psychological factors such as information processing, learning and motivation. (Morgan, 1973; Noble, Metz, Pandolf, & Cafarelli, 1973). In laboratory experiments performed by Morgan (1973) physiological responses were found to account for approximately two-thirds of the variance found in RPE. He suggested that the remaining

one-third of the total variance in RPE may be related to psychometric factors. In 1981, Morgan stated that research and practice with RPE has essentially ignored the influence of personal characteristics other than fitness on RPE. Morgan (1981) has analyzed other factors such as inconsistent use of perception by subjects. He recommends the use of retrospective reporting by subjects involving compliance with instructions or a type of subjective confidence about their success in complying. This would allow the investigator to estimate how effective the subjects are in manipulating rating of perceived exertion in relation to exercise intensity.

Cacioppo, Tassinary, Stonebraker, and Petty (1987) compiled several reasons for doubting the validity of measures based on self-reports of physiological arousal. Several factors have been identified which contribute to the invalidation of self-reports. Subjects may fail to accurately report their perception of physiological arousal due to the belief that physiological arousal following a strong excitatory stimulus diminishes more quickly than sympathetic arousal. A second factor involves the translation of internal states to verbal responses. Individual perspectives and interpretations influence the resulting verbal response and cause individual variation. A third factor involves the variability in specific physiological sensations that individuals employ to gauge their bodily state. Once again individual variability appears and threatens the validity of between- and within- subject comparisons. A fourth factors reveals that individuals are biased by past experiences, beliefs, and expectations. Additional factors which may influence self-reports include subject roles, evaluation

apprehension, demand characteristics, response biases, or experimenter bias. Subjects may be apprehensive to use the full range of the estimation scale and fail to accurately report their actual responses. The final factor includes the initial fitness level of subjects. Each subject may react differently to stimuli as a result of the varying fitness levels'. From these six factors it is possible to conclude that the physiological functions which serve as a basis for individual sensations of arousal may be too complex for direct measurement (e.g., verbal descriptions) (Cacioppo et al., 1987).

Perceived Effort During Aerobic Exercise

Training Effects

Morgan and Borg (1976) and Rejeski (1981) have suggested that physical performance may be related as much to an individual's self-perceptions of ability to perform physically as to the actual performance capacity. Individuals have been found to either increase or decrease the intensity of their perception of effort over a long-term training program (Robertson, Gillespie, Hiatt, & Rose, 1977). Studies have determined that changes in perceptual response to activity occur when exercise programs are administered (Pandolf, Burse, & Goldman, 1975; Ekblom & Goldbarg, 1971).

Borg and Linderholm (1967) discovered that four months of intense exercise could result in a modified evaluation of effort at an absolute workload. Also in 1971, Ekblom and Goldbarg determined that following an eight week training program, RPE was found to be 1.5 to 2.0 points lower at standard submaximal workloads. The RPE at maximum exercise

intensity failed to differ. Kilbom (1971) also demonstrated equivalent results when he found a reduced RPE at lower submaximal workloads and no difference in RPE at maximum exercise intensity.

Kilbom (1971) demonstrated that at the completion of an aerobic exercise training program, the metabolic requirement of a given submaximal activity was unchanged or slightly decreased. In addition, it was found that metabolic demands of a specific task were reduced when expressed as a relative percentage of maximal work capacity. From these results one could conclude that the performance of a standard workload would be perceived as involving less effort.

Investigations involving the effects of training upon RPE have produced a variety of results. Pandolf et al. (1975) found RPE to be reduced at a specific HR or VO_2 following three weeks of low intensity, long duration activity. Patton, Morgan, and Vogel (1977) found no differences in RPE following a six-minute run at 6 mph on a treadmill in military conscripts who varied in fitness levels. Following a six week training program an 11% reduction in RPE was found for all subjects during submaximal exercise. It has been proposed that differences in RPE are only manifested during intense activity due to the fact that this study only evaluated differences in RPE at low to moderate intensities. Lewis et al. (1980) observed a significant reduction in RPE at a fixed workload, following an 11-week training program performed at 75 to 80% of VO_2max.

Contrasting studies have illustrated that following training, increased workloads were associated with a wide selection of RPE values, in the range of moderate to intense RPE estimates (Doctor & Sharkey,

1971). Carton and Rhodes (1985) concluded that although reductions in RPE were determined at an absolute workload following training, no changes occurred with respect to relative exercise intensity.

Level of Fitness and RPE

Numerous investigations have determined that individuals categorized as fit or unfit rated perception of effort equally when performing standard workloads (Carton & Rhodes, 1985). Purvis and Cureton (1981) found that perceptions of effort are similar between subjects at anaerobic threshold which implies that well-trained individuals will give a lower perceived rating to a higher absolute exercise demand. Chow and Wilmore (1984) suggested that sedentary subjects who combined RPE and HR, based upon a previous graded exercise test, tended to underestimate versus overestimate training HR. The influence of fitness level on RPE needs to be further investigated before valid conclusions can be determined.

The positive relationship that has been established between RPE and relative metabolic demand leads to the assumption that RPE may be used to regulate exercise intensity (Williams & Eston, 1989). The American College of Sports Medicine (1986) determined that RPE levels of 12 to 16 (representing "somewhat hard" to "hard") on the Borg 6 to 20 scale are equivalent to a level of 50 and 85% of an individual's VO_2max values. Ratings of perceived exertion during graded exercise tests involving running and cycling indicated that ratings of 12 to 13 were equivalent to 60 to 80% of VO_2max values in most individuals (Burke & Collins, 1984; Eston et al., 1987). A strong trend towards greater reliability

between RPE and exercise intensity was determined as the work became more intense and as experience with the task increased, except at high levels of intensity (Eston & Williams, 1988).

An issue that has been recently addressed is clearly stated in a current article by Eston and Williams (1988):

> To be an effective adjunct to standard physiological and clinical responses in prescribing exercise intensity, rated perceptions of exertion must allow accurate production of targeted responses throughout the full metabolic range (p. 25).

Williams and Eston (1989) also believed that RPE can only be a useful means of determining exercise intensity once its validity across a wide spectrum of intensities, exercise modalities, and populations has been demonstrated.

The issue of extending the utility of RPE across various intensities, modalities, and populations must be addressed. In 1981 Morgan claimed that 90% of individuals can learn to rate exercise intensity or cost accurately. The question remains as to how these individuals can learn to rate exercise intensity accurately. Researchers (Loftin, Zingraf, Warren, Jones, & Brandon, 1986; Morgan, 1981) believe that the RPE scale has a potential as a "learning aid" with respect to exercise which involves a constant workload across time or pacing.

In a 1981 forecast Morgan stated:

> ...if people have trouble adjusting to a prescribed training workload adequately, we might take them to the laboratory for a learning experience of which intensity is just right for them and determine how it feels to perform that work (p. 93).

The American College of Sports Medicine (1986) agreed with Borg's statement and made the following comment on RPE:

> ... RPE can be used in conjunction with heart rate prescription methods. At the onset of a training program the participant can be instructed to exercise at a specified heart rate and to self-monitor RPE at that intensity. Once the participant has developed a knowledge of the heart rate-RPE relationship, heart rate can be monitored less frequently and RPE can be employed as the method for regulating intensity (p. 36).

Regulation of exercise intensities by RPE results in safe and reliable HR responses above 150 bpm (80% HR max), RPE above 12, and running speeds above 2.5 m/sec or 5.6 mph (Smutok et al., 1980). They suggested that the differences in HR may be due to greater HR variability within subjects at low exercise intensities. Test-retest analysis between first and second self-regulated exercise tests revealed correlation coefficients of 0.37 to 0.75 for RPE (Komi & Karrp, 1977). The lowest coefficients were found at exercise intensities below 50% of maximal HR values (Komi & Karrp, 1977). Teghtsoonian, Teghtsoonian, and Karlson (1977) tested perception of muscular effort of male club cyclists who exercised regularly. The results determined that workload detection thresholds were sensitive to muscle fatigue which could serve as a possible explanation for any existing increases in variability in RPE at high intensity workloads. Ioftin et al. (1986) and Morgan (1981) found that rarely is more than 70% of the variance between RPE and physiological measures accounted for in this relationship. Again the suggestion of a "learning effect" is made which would account for the final 30% of the variance between RPE and physiological measures.

Hage (1981) recommended that a minimum of three feedback trials be completed in order to establish the effective use of RPE as a method to control exercise intensity. Despite these findings Pandolf (1983) believed that although test-retest correlations are high for RPE in

standardized graded exercise, the day-to-day reproducibility of RPE for continuous submaximal exercise has not been established. Chow and Wilmore (1984) found that three feedback trials were sufficient to increase training HR accuracy to acceptable ranges of 10 bpm for absolute error. Eston et al. (1987) found similar results in terms of production of accurate exercise intensities based on RPE and also stated that accuracy in effort production can only occur at higher levels of RPE (13 and 17). The accuracy of effort production is lessened at lower RPE levels.

In 1987 Myles and MaClean conducted an experiment analyzing response and/or production protocols. The response protocol allowed the subject to estimate pre-selected power outputs, while the production protocol allowed the subject to produce an appropriate power output for a preselected RPE. They concluded that production protocols are safer than response protocols due to the fact that they make no assumptions with regard to physical condition of the subjects. With the production protocol the investigator selects RPE values and the subject is allowed to adjust the power output using a hand-held control. The production method makes the assumption that the subject can adjust the power output to match numerically anchored verbal expressions of effort (Myles & MaClean, 1987).

Dishman, Patton, Smith, Weinberg, and Jackson (1987) determined that the implementation of RPE and HR reinforcement strategies during a graded exercise test was effective in reducing errors in training HR during an initial field trial walk/jog. Dishman et al. (1987) performed three post graded exercise test learning trials which involved HR

feedback. Subjects were notified of any overestimation or underestimation of training HR during an exercise session. It was found that after the administration of three learning trials, errors in training HR were significantly reduced. Williams and Eston (1989) analyzed the question of whether perception of effort is either "direct", the metabolic cost of the work and the reported feelings of the exercising person are one, or "indirect" in the sense that practice and feedback are required for the accurate production of exercise intensity. The results of the study proposed that perception of effort is "indirect" supporting the belief that practice and feedback are required for accurate production of exercise intensity. A high positive correlation has been reported between RPE and physiological measures used to determine the intensity of exercise yet rarely more than 70% of the variance is accounted for in this relationship. The remaining 30% of the variance could implicate a learning effect.

Bayles et al. (1990) performed a study which determined the effect of a relatively short duration perceptual reinforcement program on the ability to perceptually replicate low, moderate, and high walking or running exercise intensities. The results determined a degree of inaccuracy shown by the subjects for the replication of an exercise HR by perceptually setting the exercise intensity. The results presented an error of approximately +/- 10 bpm. Following short practice periods consisting of three, ten minute sessions per week or practice sessions with feedback using a special perceptual reinforcement program, they determined that an improvement in the ability to perceptually replicate the selected walking and running speeds occurred. In the field exercise

situation the subjects were asked to replicate a 60% exercise intensity while jogging on the indoor track. The results found that the subjects uniformly exercised at an intensity which produced speed and HR values characteristic of the 80% treadmill speed. The results from this study found that the reinforcement program in conjunction with the Borg RPE scale improves the accuracy of perceptually regulated exercise intensity. These results only hold true at moderate to high intensities in a controlled setting.

The results of the aforementioned studies suggest that with application of practice and reinforcement techniques the use of RPE as a method of controlling exercise intensities can be extended to a wider range of exercise intensities. Further research in this area is necessary before RPE can be determined an accurate method of controlling exercise intensity across a variety of intensities, exercise settings, and modalities.

Individual Differences Affecting RPE

In field situations numerous social psychological factors influence an individual's performance. This may result in the reduction of perception of effort in relation to actual physiological status. However, during strenuous exercise, when physiological cues are emphasized, individuals may not alter their RPE (Rejeski, 1981).

Time of Day

Researchers have determined that psychomotor and mental performance tasks, including RPE, are influenced by the time of day (Faria & Drummond, 1979; Wojtczik, Makowska, Banaszkiewicz, & Romejka, 1978). The degree to which these results extend is determined by circadian rhythms.

Age and Sex

Investigators have discovered that effort perception varies with age (Arstila, Antilla, Wendelin, Vuore, & Valamaki, 1977; Bar-Or, 1977; Borg & Linderholm, 1967) and sex (Arstila et al., 1977; Rejeski, 1981). The RPE value has been determined to be higher for a given relative exercise intensity, with increasing age (Arstila et al., 1977). In contrast, Sidney and Shephard (1977) found no significant differences in RPE between young and old, or male and female subjects when work was expressed as a relative percentage of maximal aerobic power.

Duration of Exercise

Rejeski and Ribisl (1980) determined that during moderate exercise with a duration of 20 to 30 minutes, RPE was affected by the anticipated duration of the treadmill run. Near the termination of exercise, when the internal cues were maximized, the emphasis of external cues in determining RPE was diminished. Morgan (1973) stated that during a bout of exercise it is important to consider not necessarily what an individual is doing, but what the individual thinks (feels) he/she is doing.

Research has determined that during steady-state exercise, RPE continues to increase (Noble, Metz, Pandolf, & Cafarelli, 1973; Pandolf, 1972; Borg, 1973; Davies & Sargeant, 1979). Numerous proposals exist

which serve to explain this increase in perception of effort. Carafelli and Noble (1977) support the view that central factors such as ventilation continue to increase as a function of exercise duration. However local factors such as fatigue may also influence RPE and reduce the validity of the central factors theory.

In 1981, Jackson, Dishman, LaCroix, Patton, and Weinberg determined that physiological and psychological correlates of exercise performance are different in a field setting. Dishman et al. (1987) determined that approximately 18% of performance variance in the 12-minute run may be accounted for by motivation. Earlier Kinsman, Weiser, and Stamper (1973) identified three subjective groupings associated with prolonged strenuous exercise: 1) fatigue; 2) task aversion; and 3) motivation. From this research Pandolf, Burse, and Goldman (1975) created a hierarchical model for perceived exertion involving four levels of subjective reporting: A) discrete symptoms - physiological stress which contributes to the; B) subordinate level - which entails local muscular exertion, general exertion, and cardiopulmonary exertion which contributes to the; C) ordinate level- which exemplifies physical exertion, motivation, and task aversion which contributes to the; D) superordinate level- which is represented by undifferentiated exertion, that corresponds to the measured readings from Borg's RPE scale (Pandolf, 1978). These four steps help to describe the subjective reporting process which takes place during prolonged exercise periods.

Summary

Rating of perceived exertion has been established as an adjunct to HR in an effort to measure physiological strain. Currently the issue of

substantiating RPE as a valid and reliable means of monitoring exercise intensity has been proposed. In order to test the proposal researchers (Michael & Eckhardt, 1972; Morgan, 1973; Morgan, 1981; Noble, Metz, Pandolf, & Cafarelli, 1973; Skinner et al., 1973; Smutok et al., 1980; Stamford, 1976; and Ulmer et al., 1977) have analyzed individuals' abilities to reproduce various exercise intensities based upon RPE values. These studies have introduced new areas of research that need to be further explored prior to the validation of the RPE scale as a means of monitoring exercise intensity. Such factors include validity of self-reports, individual physiological and psychological variation, training effects, levels of fitness, age, sex, and duration of exercise. Due to the fact that RPE encompasses both physiological and psychological parameters, investigators have found it difficult to control extraneous variables. Thus, this chapter has briefly summarized results of various RPE studies. However, no conclusive results can state that RPE can or can not be used as a moderator of exercise intensity.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Twenty-two female and four male undergraduate, Physical Therapy students at the University of Wisconsin-La Crosse participated in this study. The subjects ranged in age from 20-36 years and had little or no previous experience using the Borg RPE scale. The subjects were informed of the testing procedures and the data to be collected. Each subject signed an informed consent prior to testing (see Appendix A).

Experimental Procedures

VO_2max

The Q-Plex 1 Cardio-Pulmonary System (Quinton) was used to analyze expired air and determine oxygen consumption (VO_2), and respiratory exchange ratio (RER) during the VO_2max tests. The Q-Plex 1 was calibrated fifteen minutes prior to the testing of each subject, which included temperature and pressure adjustments in addition to ventilation and gas settings. Subjects reported to the laboratory and were weighed on a Health-O-Meter scale to the nearest pound. After collecting descriptive data on each subject their name, age, height, and weight values were entered into the Q-Plex 1 for future reference.

The subject was fitted with a UNIQ CIC Heartwatch which monitored HR throughout the testing session. The monitor was placed over the left side of the chest with the HR electrodes recording the subject's HR. The accompanying HR watch produced the actual HR value to allow for easy recording of the HR during testing. Resting HR values were obtained prior to testing following a five minute rest period while the subject was sitting.

Prior to the actual VO_2max test the subject was given explicit instructions regarding the RPE scale. The subject read the following instructions while referring to the chart displaying the scale (Morgan & Borg, 1976).

> You are now going to take part in a work test. You will be walking and running on the treadmill while we are measuring various physiological functions. We also want you to try to estimate how hard you feel the work is; that is, we want you to rate the degree of perceived exertion you feel. By perceived exertion we mean the total amount of exertion and physical fatigue, combining all sensations and feelings of physical stress, effort and fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath or work intensity, but try to concentrate on your total, inner feeling of exertion. Try to estimate as honestly and objectively as possible. Don't underestimate the degree of exertion you feel, but don't overestimate it either. Just try to estimate as accurately as possible (p. 395).

After the five minute rest period a heart value was recorded and the subject received a brief explanation on the VO_2max testing procedure. A brief practice session was performed to allow the subject to adapt to treadmill walking.

Initial Test

The actual VO_2max test was preceded by a discontinuous submaximal test performed at two intensities, low and moderate. A five minute

warm-up at 0% grade and a speed of 3.0 mph was conducted. Following the warm-up the treadmill speed was increased to 4.0 - 5.0 mph (depending upon age, sex, and physical conditioning level) for three minutes to allow the HR to stabilize. The goal of the low intensity initial test was to allow each subject to attain a HR value between 115-125 bpm. Once this HR range was achieved the work intensity remained constant for an additional two minutes and an RPE value was obtained during the last thirty seconds of that stage. The low intensity test was designed to "calibrate" the subject's perceptual response with his/her HR. The low intensity HR range of 115-125 bpm was selected to obtain the subject's RPE value at a lower exercise intensity. The subject performed a brief cool-down on the treadmill and was seated until their HR value was less than 100 bpm.

The subject was then connected to the Q-Plex 1 through means of a mouthpiece and headgear. The Q-Plex 1 was started when the subject began the second warm-up session for the moderate intensity test. The subject performed a brief warm-up session at 0% grade and a speed of 3.0 mph. Following the warm-up the treadmill speed was increased to 5.0-6.0 mph (depending upon age, sex, and physical conditioning level) for three minutes to allow the HR to stabilize. The goal of the moderate intensity test was to allow each subject to attain a HR value between 145-155 bpm. Once the HR range was achieved the work intensity remained constant for an additional two minutes and an RPE value was recorded during the last thirty seconds of the stage. The moderate intensity test was designed to "calibrate" the subject's perceptual response with his/her HR. The moderate intensity HR range of 145-155 bpm was selected

to obtain the subject's RPE value at a moderate exercise intensity.

The achievement of a VO_2max value was obtained immediately following the moderate intensity test. The speed of the treadmill was increased to approximately 6.0 mph for females and 7.0 mph for males. A 2% increase in grade occurred every two minutes until a maximal value was obtained. Throughout the test the Q-Plex 1 recorded VE ($l \cdot min^{-1}$), VO_2 ($l \cdot min^{-1}$ & $ml \cdot kg^{-1} \cdot min^{-1}$), and RER. Heart rates were recorded every minute and RPE values were observed every two minutes.

The following two tests were randomized with half of the subjects performing the treadmill replication test first and half of the subjects performing the track replication test first. This sequence was then reversed for the subject's second test.

Treadmill Replication

The treadmill replication test was completed no more than seven days after the initial test for half of the thirteen subjects and no more than seven days after the track test for the remaining thirteen subjects. This test allowed subjects to regulate their own exercise intensity to match each of the calibration points or RPE intensities. The subject entered the laboratory, was fitted with a heart rate monitor, and a resting HR value was recorded. The subject rested until his/her HR value fell within 5 bpm of the resting HR value obtained during the initial test. The subject again read the following set of instructions (Morgan & Borg, 1976):

> You are now going to take part in a work test. You will be walking and running on the treadmill while we are measuring your heart rate. We have preselected two RPE levels which we wish for you to produce by means of manual control of the treadmill speed.

> The speed of the treadmill will be controlled by the investigator and you will notify the investigator to increase or decrease the treadmill speed to match the preselected RPE value. The RPE levels will be presented in a randomized order and you will be allowed three minutes to adjust the treadmill speed to the level of effort you believe matches the predetermined RPE level. You will remain at your selected intensity for two minutes. The adjustment you make in terms of treadmill speed should be representative of the level of perceived exertion we have selected. Remember, perceived exertion is the total amount of exertion...(p. 395).

After reading the instructions the subject was randomly given one of two RPE values previously experienced and asked to replicate the exercise intensity by asking the investigator to adjust the treadmill speed. Once the subject felt he/she had reached the desired intensity, the treadmill speed remained constant for at least two minutes to allow the HR to stabilize. Following the first RPE replication the subject was seated until his/her HR was less than 100 bpm. The second previously experienced RPE was then replicated similar to the first with the subject monitoring the treadmill speed by means of communication with the investigator.

Track Replication

The track replication test was completed no more than seven days after the initial test session for half of the thirteen subjects and no more than seven days following the treadmill test for the remaining thirteen subjects. The subject entered the running track area in the fieldhouse and was fitted with a HR monitor. Resting HR values were monitored until they were within 5 bpm of those obtained during the previous tests. The subject again received the following instructions (Morgan & Borg, 1976):

> You are now going to take part in a work test. You will be walking and running on the track while we are measuring your heart rate. We have preselected two RPE levels which we wish for you to produce by means of adjusting your walking or running speeds. The RPE levels will be presented to you in a randomized order and you will be allowed three minutes to adjust your walking or running speed to the level of effort you believe matches the preselected RPE value. You will remain at your selected intensity for two minutes. The adjustments you make in terms of walking or running speed should be determined by the level of perceived exertion we have selected. Remember, perceived exertion is the total amount of exertion...(p. 395).

After reading the instructions the subject was randomly given one of two RPE values previously experienced and asked to replicate the exercise intensity by adjusting their walking/running speed. Once the subject felt he/she had reached the desired intensity the HR watch monitor was activated. The subject was asked to maintain the walking/running speed for two minutes to allow the HR to stabilize. Following the first RPE replication the subject was seated to allow the HR to decrease to at least 100 bpm. The replication of the second previously experienced RPE value was then completed as previously described.

Statistical Analyses

After completion of testing the means and standard deviations of the subjects' physical characteristics and maximal exercise data were calculated. In addition, the means and standard deviations of the subjects' HR and RPE values for each intensity and mode were computed. The HR values for each intensity and mode were analyzed using a two-way analysis of variance with repeated measures to determine if there were significant ($p<.05$) differences in the subjects' abilities to replicate

exercise intensities.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to evaluate the use of RPE as a frame of reference for the production of a range of walking and running intensities by young men and women. Means and standard deviations were computed for physical characteristics and maximal exercise data for each subject as well for HR and RPE values for each intensity and mode. Data obtained from the study were analyzed using a 2 x 3 factorial design analysis of variance with repeated measures. The first factor compared HR at RPE levels of low and moderate intensities. The second factor involved comparing HR at various testing modes: initial treadmill test, treadmill replication and track replication.

Subjects

Twenty-two women and four men (N=26) who were enrolled in the Physical Therapy program at the University of Wisconsin-La Crosse volunteered to participate in this study. Each subject completed three exercise tests conducted over a three week period. The initial assessment consisted of a submaximal exercise test followed by a maximal exercise test. This initial test served to establish RPE values representing low (115-125 bpm) and moderate (145-155 bpm) exercise intensities as well as maximal values. A second test involved a

treadmill replication session in which subjects were asked to replicate low and moderate RPE values while exercising on the treadmill. A third test involved a track replication session in which subjects were asked to replicate the low and moderate RPE values during track running. The initial test was completed by all subjects with the order of the second and third test randomly assigned. Final statistical analysis included a total of twenty-two women and four men. Four subjects were unable to complete all three tests and were excluded from the study.

Physical Characteristics

Means and standard deviations for physical characteristics of the subjects are shown in Table 1. Males and females were grouped together in terms of physical characteristics. Subjects' heights ranged from 63-76 inches with a mean of 66.5 inches. Their weight ranged from 109-220 lbs with a mean weight of 147.6 lbs. Resting HR values displayed a great variance with a minimum value of 46 bpm and a maximum value of 99 bpm. These values displayed a wide range due to various factors such as the individuals' diverse fitness levels, inter-individual test apprehension, and inter-individual RHR ranges.

Maximal Exercise Data

Means and standard deviations for maximal exercise data of the subjects are shown in Table 2. All subjects performed the VO_2max test and fulfilled the required VO_2max criteria which included a plateau or leveling off of VO_2 ($< 150\ l \cdot min^{-1}$) with increasing workload and an respiratory exchange ratio value greater than unity (>1.0).

Table 1

Means and Standard Deviations for Physical Characteristics of Subjects (N=26)

Variable	Mean	Standard Deviation
Age (yrs)	22.3	3.9
Ht (in)	66.5	3.1
Wt (lbs)	147.6	26.8
RHR (bpm)	70.0	11.9

All subjects ranked in the fair to high category in terms of VO_2max scores (American Heart Association, 1972). The range of VO_2max values were 33.8 $ml \cdot kg^{-1} \cdot min^{-1}$ to 64.4 $ml \cdot kg^{-1} \cdot min^{-1}$. Maximal HR values ranged from 178 to 206 bpm with a mean maximal HR of 191.2 bpm.

Maximal RPE values ranged from 16 to 19 with a mean maximal RPE of 18.2. In some cases the subject's final recorded RPE value failed to reflect their actual physiological status in terms of achieving maximal oxygen consumption. This may indicate that the subjects were not accurately assessing their RPE selection and were underestimating their actual perceptual response.

Initial Test

Means and standard deviations of HR values were calculated from the three exercise tests and RPE intensities (see Table 3). The initial exercise test consisted of the submaximal treadmill test in which subjects were asked to select an RPE value while exercising at a HR range of 115-125 bpm, representing low intensity exercise.

Table 2

Means and Standard Deviations of Maximal Exercise Data

Variable	Mean	Standard Deviation
VE ($l \cdot min^{-1}$)	108.1	26.8
VO_2 ($l \cdot min^{-1}$)	3.1	0.8
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	46.9	7.3
RER	1.2	0.1
HR (bpm)	191.2	8.0
RPE	18.2	0.9

The subjects were later asked to select an RPE value while exercising at a HR range of 145-155 bpm, representing moderate intensity exercise. This resulted in an average RPE of 10.0 for the low intensity and 12.7 for the moderate intensity exercise session. During the initial test an RPE of 10 corresponded to a mean HR of 121.2 bpm and an RPE of 12.7 corresponded to a mean HR of 151.7 bpm. The RPE value of 10 was originally designed by Borg (1973) to correspond to a HR of 100 bpm. The subjects in this study underestimated this exercise intensity in relation to the HR by 21.2 bpm. Originally the RPE value of 12.7 was designed to correspond to a HR of 127 bpm. However, the subjects' HR values were 151.7 bpm, and thus they underestimated their exercise intensity in relation to HR by 24.7 bpm. It is noteworthy that these subjects underestimated their physiological state perceptually, a condition that persisted in their subsequent tests.

Table 3

Means and Standard Deviations of Heart Rates at Various Exercise Modes and Intensities

Condition	Test		
	Initial	Treadmill	Track
Low[1] (RPE=10)	121.2 2.8	126.8 23.3	141.6[2] 25.3
Moderate (RPE=12.7)	151.7 2.7	154.6 21.7	161.4[2] 20.1

Note. [1] moderate > low ($p<.05$)
[2] track > treadmill & initial ($p<.05$)

Results of Replication Tests

A 2 x 3 factorial design ANOVA with repeated measures was performed to analyze the effects of mode and intensity. After the execution of Scheffe's post hoc statistical analysis it was determined that the main effects of mode displayed a significant ($p<.05$) difference in HR values between the treadmill replication test (140.7 bpm) and the track replication test (151.5 bpm), but not ($p<.05$) between the initial test (136.5 bpm) and the treadmill test (140.7 bpm).

Low and Moderate Intensity

The effect of the low and moderate levels of exercise intensity demonstrated a significant ($p<.05$) difference between the HR values corresponding to the two exercise levels regardless of mode. The overall HR values for the low level of intensity were 129.9 bpm and 155.9 bpm for the moderate level of intensity. These results were expected due to the design of the experiment which indicated different workloads that reflected HR values between 115-125 bpm and 145-155 bpm for low and moderate intensities, respectively.

Eston et al. (1987) and Smutok et al. (1980) found that the achievement of accurate effort production from RPE is reasonably accurate at higher levels of RPE, but less accurate at lower RPE levels (12 and below). Low correlation coefficients between RPE and HR were found at exercise intensities below 50% of maximal HR value by Smutok et al. (1980). Purvis and Cureton (1981) determined that the achievement of accurate effort production from RPE was reasonably accurate at higher levels of RPE (13 & 17), but less accurate at its lowest level. It is noteworthy that the results of this study indicated that the subjects accurately replicated both low and moderate exercise intensities in the controlled or treadmill setting.

Initial Versus Treadmill

Although the subjects slightly overestimated the intensity of the low exercise by 5.6 bpm and the moderate intensity exercise by 2.9 bpm when replicating the RPE values 10.0 and 12.7, respectively in the controlled or laboratory setting, these differences were not significant ($p<.05$). These results indicate that when the same mode (i.e., treadmill) is used in a controlled environment the subjects can accurately replicate their RPE.

Initial Versus Track

A significant ($p<.05$) difference was found when comparing the HR values between the initial test (136.5 bpm) and the track replication test (151.5 bpm). This indicated that the subjects overestimated the amount of physiological effort necessary relative to their perception of effort. Simply stated, their physiological responses or requirements were higher than what they felt they were.

Track Versus Treadmill

The subject's physiological responses to the track test were

significantly ($p<.05$) higher (151.5 bpm) compared to the treadmill (140.7 bpm) responses. These results correspond to the comparison between the track and intial tests. The subjects again appeared to have the ability to duplicate their effort in a treadmill, but not a track setting. The subjects in this study had little or no previous experience with the Borg's RPE scale and monitoring their feelings of exertion. The result of their lack of experience rating their feelings of exertion was reflected in the underestimation of exercise intenstiy when removed from a controlled setting.

Discussion

The results of this study are similar to a study conducted by Bayles et al. (1990) in which subjects were asked to replicate 60% intensity while jogging on an indoor track. Bayles' et al. subjects had experienced one of two possible treatment sessions. The first group participated in a three session practice period at the 60% intensity level and/or a feedback session with the use of perceptual reinforcement. Subjects uniformly exercised at an intensity which produced speed and HR values representative of 80% intensity when asked to replicate 60% intensity in a field setting (Bayles et al., 1990). In both field situations the subjects overestimated the exercise intensity when based upon the RPE scale. Bayles et al. (1990) also determined that the administration of a reinforcement program in conjunction with the Borg RPE scale improved the accuracy of perceptually regulated exercise intensity. These results were found only at moderate to high intensities in a controlled setting (Bayles et al., 1990).

In the 1987 study conducted by Dishman et al., it was found that the implementation of HR feedback significantly reduced errors in training HR during effort production tests. Notifying the subjects of

overestimation or underestimation in training HR allowed the subjects to experience the correct exercise intensity and in turn produce the correct exercise intensity. Hage (1981) recommended a minimum of three feedback trials be completed in order to establish effective use of RPE as a method to control exercise intensity. His study suggested that more tests be completed in order to increase subject experience with the various exercise intensities in the field setting. Jackson et al. (1981) found that physiological and psychological correlates of exercise performance are different in a field setting. This finding may help to explain the inaccuracy produced in the replication of exercise intensities in an uncontrolled/track versus a controlled/laboratory setting.

Eston and Williams (1988) determined that HR is known to fluctuate on an intra- and intersubject basis as a result of environmental and emotional influences. The environmental change in the exercise setting could play a role in the significant difference between HR values in the controlled versus the uncontrolled setting.

The significant difference between the HR values in the laboratory and the track setting in the present study must be considered when establishing actual exercise prescriptions using the RPE scale. The RPE scale has not been validated as a accurate method to monitor exercise intensity and, therefore, must not be the sole means of monitoring exercise intensity.

Factors Influencing RPE

Other factors that should be discussed in relation to RPE are psychometric factors. In 1973 Morgan determined that physiological responses accounted for approximately two-thirds of the variance between RPE and a subject's actual physiological status. The remaining one-

third of the variance account for psychometric factors. Later in 1981 Morgan pointed out that personal characteristics influence RPE and must be considered when analyzing the RPE/HR relationship. He recommended that subjects report how confident they feel in accurately using Borg's RPE scale. In the present study some subjects indicated that they did not feel confident with their RPE selection and "guessed" at a selection instead of perceptually analyzing their physiological status.

Another psychometric factor is motivation. Dishman et al. (1987) determined that approximately 18% of performance variance in the 12-minute run may be accounted for by motivation. Jackson et al. (1981) also noted that psychological correlates of exercise such as motivation are different in a field setting. The motivational factor may have been higher in the uncontrolled or track setting due to the atmosphere of the setting, and therefore, accounted for the underestimation of RPE in this current study.

An individual's level of fitness has also been shown to influence their RPE responses. Purvis and Cureton (1981) determined that well-trained individuals will give a lower RPE for a given workload than the untrained. This would be expected since their HR responses to a given workload would also be lower. As indicated previously, as an average the subjects in the present study could generally be considered above average in fitness, but not well-trained.

Finally, the issue of exercise duration must be discussed. It was observed that numerous subjects inquired as to the duration of the three exercise tests and pointed out that they would have been better able to select an accurate RPE value if they had some conception of the duration of the exercise session. Rejeski and Ribisl (1980) determined that during moderate exercise with a duration of 20 to 30 minutes, RPE was

affected by the anticipated duration of the treadmill run. They also pointed out that at the termination of the exercise session, the internal cues were maximized and the external cues were minimized. As stated by Morgan (1973) the subject must consider not necessarily what he/she is doing, but what the individual feels he/she is doing. In this particular study the subjects were told to focus on their immediate feelings and to not consider how they would feel minutes later.

Summary

Numerous factors influence the subjects' abilities to replicate the RPE exercise intensities. The results of this study indicated that subjects were more accurate at replicating previously experienced RPE values in a controlled or laboratory setting versus an uncontrolled or track setting. In order to work towards validation of the RPE scale as an accurate method of monitoring exercise intensity it is necessary to focus on this discrepancy. It may be possible to reduce replication errors through the use of practice sessions which reinforce the correct training intensity. In addition, the use of retrospective reporting by the subjects may assist the investigator in the determining how effective the subjects feel they are using the RPE scale.

The key to validating the RPE scale as a method to monitor exercise intensity seems to lie in experience. All of the subjects in this study had little or no previous experience with the RPE scale, therefore, they had difficulty replicating RPE levels. It was most difficult to replicate RPE levels in an uncontrolled setting where no constraints were placed on the subjects. The results of this study indicate that additional experience with the RPE scale is needed to improve its applicability to field situations.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

It has been determined that RPE can only be a useful means of determining exercise intensity once its validity across a wide spectrum of intensities, exercise modalities, and populations has been demonstrated (Williams & Eston, 1989). Numerous studies have analyzed the validity of RPE, but none have claimed that effort production can be accurately replicated on the basis of Borg's RPE scale.

The purpose of this investigation was to evaluate the use of RPE as frame of reference for the determination of a range of walking and running intensities. The results of this study were based on a group of twenty-two females and four males who completed three exercise tests. The initial exercise test served as a calibration test in which the two RPE intensities (low - 10.0; moderate - 12.7) were established on the basis of two HR ranges (115-125 bpm; 145-155 bpm). Upon obtaining the established HR ranges, the subjects completed a VO_2max test. The final two exercise tests involved the replication of the two RPE (10.0 & 12.7) values in a controlled or treadmill setting and a uncontrolled or track setting.

By design the low RPE resulted in a significantly ($p<.05$) lower HR response than the moderate RPE. This indicated that the subjects were able to differentiate between the two RPE intensities when asked to replicate them.

The results indicated that the track replication test displayed significantly ($p<.05$) higher HR values than the treadmill replication test. In addition, the track replication test also displayed significantly ($p<.05$) higher HR values than the initial test. There were no significant ($p<.05$) diferences in HR responses between the initial and treadmill tests. These results demonstrate that the subjects as a whole underestimated exercise intensity in relation to their actual HR values when exercising in an uncontrolled/track setting.

No significant interaction was found between the specific exercise intensities and the ability to produce those intensities in various exercise settings: 1) track and treadmill test; and 2) track and submaximal test.

On the basis of these results it is not possible to validate the use of RPE as a frame of reference for the production of a range of walking and running intensities. The subjects failed to accurately replicate both RPE values in the uncontrolled or track setting, resulting in the failure to satisfy the validation criteria stated by Williams and Eston (1989). The results of this study can be applied to many exercise settings. Directors and leaders of exercise programs must be aware that participants need to be monitored through a variety of methods during exercise sessions. The sole use of RPE does not provide a safe and reliable method of determining exercise intensity. Other

physiological measurements must be utilized in conjunction with the RPE scale, such as HR response, blood pressure response, VE and VO_2. By analyzing the overall physiological state of the participant the correct training intensity can be determined and experienced by the participant. In turn, the participant learns the correct training intensity and better understands how to correctly utilize the RPE scale. Further study in this area is necessary prior to the validation of RPE as a useful means of determining exercise intensity.

Recommendations

Upon completion of this investigation, it was recommended that a future study be conducted, similar to the present study with the following modifications:

1. Enlarge sample size. By means of a larger sample size the results could be more accurately related to the general population.

2. Include physical activity questionnaire. A physical activity questionnaire would provide more information on the subject's fitness level, in addition to the VO_2max test. How often the subject exercises per week, what type of exercise, and the duration of exercise could all influence the subject's ability to determine an RPE value.

3. Include retrospective reporting by subjects involving compliance with RPE instructions and their success in complying. It is necessary to determine how effectively the subjects feel they are using the RPE scale. If the subjects do not feel they are accurately selecting an RPE value the scale is of no use and they must be taught how to properly use the scale.

4. Extend the number of experiences with the pre-established RPE levels. Increasing the number of experiences with the pre-established RPE levels will allow the subjects to experience the correct exercise intensity and in turn learn to train at the proper exercise intensity.

5. Provide feedback to subjects in relation to HR values. Heart rate feedback will allow the subjects to determine if they are overestimating or underestimating the selected HR range. Once again, the subjects will experience the correct training HR range and will learn to train at the proper exercise intensity.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

RATING OF PERCEIVED EXERTION

Your written consent is needed prior to your participation in this study. Please read this consent document carefully and sign your name in the space provided below.

PURPOSE: To measure maximal aerobic capacity through a series of maximal and submaximal tests.

PROCEDURES: A group of university physical therapy students will be recruited to participate in a series of trials. You will participate in three, thirty minute trials.

Trial 1 will involve a maximal exercise test (Max VO2) performed on a treadmill. The following data will be collected: 1) Oxygen consumption- This will entail wearing a mouthpiece and headgear; 2) Heart rate -A heart rate monitor will be strapped around your chest throughout the trial; and 3) RPE- You will be asked to rate your measure of perceived exertion periodically throughout the test.

Trial 2 will involve the production of previously established RPE values by means of subjective exercise regulation. This will be accomplished by allowing you to adjust your walking or running speed while exercising on the treadmill. The following data will be collected: 1) Heart rate and 2) RPE. Trial 3 will involve the production of previously established RPE values by means of subjective exercise regulation. This will be accomplished by allowing you to adjust your walking or running speed while exercising on a track. The following data will be collected: 1) Heart rate and 2) RPE.

The total time for each of the three sessions will be forty-five

minutes to an hour, a total of 3.0 hours for the entire study.

DISCOMFORTS OR RISKS: There exists the possibility of certain changes during the test. These changes may include abnormalities of heart rate and in rare cases cardiac arrest. Prior to testing please make the investigator aware of any known health risks that may limit your cardiovascular or physical performance. Discomforts which may arise during the collection of oxygen include dryness in the mouth and feelings of restricted respiration. Every effort to minimize risks and discomforts will be made by the investigator.

BENEFITS: Your participation in this study will serve to contribute to the advancement of science in the field of human performance research. By participating, you should expand your knowledge of rating of perceived exertion and its relationship to exercise training.

QUESTIONS AND ANSWERS: Questions you may have regarding any of the procedures are welcomed and encouraged. If you have any doubts or concerns, please ask any of the investigators for further explanation.

WITHDRAWAL: You are free to withdraw consent and discontinue participation at any time without penalty.

CONFIDENTIALITY: All data obtained will be kept confidential. No data will be identified by name or any other means in summaries, publications, or reports that result from testing.

_____

Investigator's Signature

_____

Date

Lisa M. Schroeder, Investigator
Department of Physical Education
University of Wisconsin-LaCrosse, WI 54601
Telephone (608) 788-7400

I acknowledge that I have read and understood the Informed consent document in its entirety. I have also been informed and understand the foreseeable discomforts, risks, and benefits. I, the undersigned, give my consent for participation in the Rating of Perceived Exertion study.

_____

Date

_____

Signed

_____

_____

Address

_____

Telephone

APPENDIX B

DATA SHEET - TRIAL 1

Appendix B

Subject's Name_____ Date_____

Age_____ Height_____ Weight_____ Resting Heart Rate_____

Trial 1

Heart Rate Production _____

Time (min.)	Grade	Speed (mph)	Heart Rate (bpm)	RPE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Resting value _____

APPENDIX C

DATA SHEET - TRIAL 2

Appendix C

Subject' Name_____ Date_____

Age_____ Height_____ Weight_____ Resting Heart Rate_____

Trial 2

RPE Effort Production_____

Time (min.)	Speed (mph)	Heart Rate (bpm)	RPE
1			
2			
3			
4			
5			
6			
7			
8			

RPE Effort Production _____

1			
2			
3			
4			
5			
6			
7			
8			

APPENDIX D

DATA SHEET - TRIAL 3

Appendix D

Subject's name_____ Date___

Age_____ Height_____ Weight_____ Resting Heart Rate_____

Trial 3

RPE Effort Production_____

Time (min.)	Speed (mph)	Heart Rate (bpm)	RPE
1			
2			
3			
4			
5			
6			
7			
8			

RPE Effort Production_____

1			
2			
3			
4			
5			
6			
7			
8			