RELATIONSHIP BETWEEN RPE AND PHYSIOLOGICAL MEASURES OF EXERCISE: A META-ANALYSIS

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AN ABSTRACT OF

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

School of Health Education, Counseling
Psychology, and Human Performance

1987

ABSTRACT

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The purpose of this review was to determine how the relationship between ratings of perceived exertion (RPE) and selected physiological measures during exercise is modified by variables such as exercise mode and subject age. Twenty-three studies using Pearson correlation coefficients to compare RPE with physiological measures were changed to Z scores using the Fisher Z transformation.

A test of homogeneity of correlations for specific RPE-physiological measure relationships determined whether the correlation groups were more varied than would be expected from sampling variability. Significant excess variation was found for the RPE-heart rate relationship. To find what study features modified this relationship, ANOVA-like comparisons were used. Results indicated that four study feature groupings yielded significant results both between and within study feature classes. These results implied that multiple study features influence the strength of the relationship between RPE and HR.

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To My Family

ACKNOWLEDGMENTS

I wish to acknowledge and thank a special group of individuals who, with their professional expertise and genuine belief in human achievement, have helped me to complete this master's thesis. Without their guidance, my educational experience over the past five years would have been incomplete.

First, I wish to thank my committee chairperson and advisor, Dr. Deborah L. Feltz, for her academic expertise and unwavering intellectual support that has become an integral part of this thesis and has contributed to my academic, professional, and personal growth. I also wish to thank my committee member, Dr. Betsy Becker, for her statistical advice, time, enthusiasm, and patience that were essential to this project. I wish to thank Dr. Martha E. Ewing for her conceptual understanding of what I wished to achieve upon completion of this thesis. I would also like to thank my remaining two committee members, Dr. Paul Vogel, for his shared interest in the perceived exertion literature, and Jeanne Foley for her technical expertise in the area of exercise physiology. Also, I especially wish to thank Nancy Heath, my typist, for her grammatical knowledge, typing skill, and continuous support during my rewrite and editing phases.

To my family, a very special thank you is in order. To my mother: thank you for your unending support and genuine belief that I could attain this goal. To my father: thank you for teaching me the mental skills necessary to overcome fear of success. And to my brother, Brian, for paving that road to success.

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CHAPTER I

INTRODUCTION

Nature of the Problem

Perceived exertion is an individual's perceptual interpretation of the intensity of physical exercise. This interpretation involves the culmination of various physiological cues. Unfortunately, it is not clear how individuals sense physiological cues, and what cues they select to make their interpretation of physical exertion (Mihevic, 1981). The cues that individuals select to make their interpretation of physical exertion seem to change as testing circumstances change. Recent researchers have not been able to determine any clear pattern surrounding these circumstances. The potential significance of this problem is evident in the clinical use of perceived exertion information to formulate exercise perceptions. If the relationship between perceived exertion and testing circumstances, such as exercise mode and protocol, environmental conditions, and patient characteristics is not clearly understood, the prescription could be inaccurate.

In the studies that have attempted to identify the physiological cue(s) that are related to perceptual interpretations, investigators have typically correlated measures of perceived exertion with various physiological measures of exercise intensity to examine the relationships between them. From this research, two theoretical viewpoints have emerged. One viewpoint suggests that one primary physiological cue influences the perceptual evaluation of physical work; the other viewpoint suggests the integration of multiple physiological cues influence the perception of exercise (Pandolf, 1983).

The Integration of Multiple Cues Concept

Borg (1962a) developed several methods to measure perceptual effort based on the integration concept. He believed perception of effort is based on a "Gestalt" interpretation and suggested that perceptual estimates are a complex combination of cues. For work of short duration, he used a system of "halving" to measure intraindividual perceptual ratings. This method required the subject to perform at one half of the intensity of a previous standard level of work as a measure of perceived effort. Borg found that these estimates increased proportionally with physical work load. For work of long duration, Borg needed to counter subject memory error and aerobic adaptive effect. Accordingly, he used ratio estimations to measure perceptions. This technique required the subject to estimate the percent of current work by comparing it to a previous standard level of work. These estimates also increased proportionally with physical work load.

Borg (1978) developed a third method which measured interindividual perceptions of the same work. This method employed a category scale, designed to increase parallel to absolute heart rate (HR) as physical work increased. The scale ranges from 6 to 20 to parallel HR readings of 6- to 200 bpm. Measures from this scale are referred to as ratings of perceived exertion (RPE). This 15-point scale is simple to use, and is, therefore, applied regularly in clinical settings. However, the interpretation of the scores obtained from this measure of RPE is not parsimonious. The scores are supposed to represent a perceptual response to a "Gestalt" of physiological cues, but there is no evidence to support this contention.

The Primary Cue Concept

Ekblom and Goldbarg (1971) proposed a different interpretation of RPE scores based on the second concept that perceptual ratings can originate from one primary cue or primary-cue group. They identified two groups of physiological cues: (a) a local factor group dealing with feelings of strain in exercising muscles and joints, and (b) a central factor group reflecting sensations that involve the cardiovascular system. Ekblom and Goldbarg used the two- factor approach to compare RPE to physiological responses during exercise. They found RPE were strongly related to local factor indicators, such as blood lactate, during bicycling, and were related to central factor indicators, such as HR during running. Ekblom and Goldbarg proposed that while bicycling, muscular strain was a dominant perceptual sensation and that while running, rapid breathing was a dominant perceptual sensation. Their study concluded that the type of exercise determined the dominant physiological cues that were perceived and rated. Whether there is a difference between the strength of the relationship of RPE to local factors and the strength of the relationship of RPE to central factors is still uncertain. Unfortunately, there are too few studies correlating RPE with local factors to draw any definitive conclusions concerning this question.

Pandolf (1977) and Gamberale (1972) also considered the relationship of RPE to separate local and central factor groups. Both researchers used a technique called Differentiated RPE. This approach required subjects to rate their perceptions using a local muscular rating, a central cardiopulmonary rating, or an overall general rating. Both studies used Borg's 15-point (1970) scale as the rating instrument. Pandolf found local RPE correlated significantly higher than central RPE with physiological responses to exercise on a bicycle ergometer. For treadmill walking, he found no difference. Gamberale found significant perceptual ratings from the local arm region for weight lifting, and found both significant local and central ratings for bicycling. This method of differentiating RPE does help the researcher to compare the perceptual interpretation of exercise with one primary physiological response. However, this method does not guarantee the same results across all exercising circumstances. The results of these two studies show that exercise mode seems to influence the relationship of RPE to physiological cues. In fact, Mihevic (1981) has suggested that local or central factors or physiological measures in general cannot be compared to perceptual measures without considering the modifying study features that occur during exercise.

Features That Modify the RPE-Physiological Cue Relationship

In addition to exercise mode, other study features that may modify the relationship between RPE and physiological cues include exercise intensity, duration, and protocol. Several studies have examined additional variables that may affect the relationship of RPE to physiological measures, such as the intensity, speed, timing, and muscle involvement of the work as well as individual differences, such as age, sex, body composition, and training status (Pandolf, 1978). Altitude (Horstman, Weiskoff, & Robinson, 1979), environmental temperature (Skinner, Hutsler, Bergsteinova, & Buskirk, 1973a), autonomic nervous system blocking agents (Ekblom & Goldbarg, 1971), and hypoxic mixtures of gas (Allen & Pandolf, 1977) also have been shown to influence perceptual ratings. These studies suggest that the testing procedures, the environment, and subject characteristics seem to modify the relationship between RPE and physiological responses to exercise.

The results of these studies reveal a major problem in the perceived exertion literature: RPE seem to change when testing circumstances are manipulated. This problem exists whether RPE are based on a Gestalt of physiological cues or one primary cue group. Three reviews (Borg & Noble, 1974; Pandolf, 1978, 1983) have examined the research in an attempt to find some answers to this problem.

Borg and Noble (1974) found in their review that before perceptual ratings can be used as a primary indicator of physical stress, various dimensions of exertion, such as body part involved and length of exercise time, must be analyzed. Also, they argued that variables, such as exercise modality and intensity, must be investigated.

Pandolf (1978) compiled research investigating the two-factor approach and evaluated the relative involvement of various physiological cues with RPE. He found that the dominance of either central or local factors in RPE could not be determined without considering the testing conditions. Pandolf believed further investigations were needed to refine measuring techniques and to identify the relationship between physiological cues and unique variables within specific studies. Pandolf (1983) conducted a second review and found, once again, the degree of influence of either factor group or both seemed dependent on the modifying agents within the study groups.

These three reviews restated the problem and provided additional evidence of its existence. However, they left many questions unanswered, such as which modifying agents provide the greatest degree of influence on RPE. From these reviews, the following study features have been identified as potential modifiers of RPE: (a) exercise modality, (b) exercise intensity, (c) exercise duration, (d) exercise protocol, (e) the use of drugs or blocking agents, (f) environmental conditions, such as altitude and temperature, and (g) the age, sex, body composition, activity level, and training status of the subject.

Meta-analysis provides a method by which a quantifiable interpretation of the magnitude of influence among these potential modifying study features can be obtained. A meta-analysis, as Glass (1977) describes it, is an "analysis of analyses, i.e., the statistical analysis of findings of many individual analyses" (p. 252). A meta-analysis is, therefore, referred to as a review, rather than a single analysis. The studies used in this type of review must share a "common conceptual hypothesis." The perceived exertion studies share the hypothesis that there is a relationship between RPE and physiological measures during exercise.

The statistical procedures in meta-analysis involve using a test of homogeneity. Accordingly, consistency of the studies' findings was tested for evidence of a single underlying population correlation. If the test is significant, the correlations are considered heterogeneous or different across studies; if the test is not significant, the correlations are considered homogeneous. This statistical approach provided a clearer understanding of whether study features modified the relationships between RPE and physiological measures.

Statement of the Problem

The purpose of this study was to determine the whether various study features affect the strength of the relationship between RPE and specific physiological responses to exercise. The methodology to be used for this procedure is meta-analysis.

Significance of the Study

In recent years RPE have become part of a battery of measures used during the clinical evaluation and graded exercise testing of patients with cardiovascular disorders. Perceptual measures are sometimes ~~used as~~ the primary source of information used to formulate exercise prescriptions when cardiovascular patients are taking medications which alter normal physiological responses to physical exercise.

If the effects of exercise mode and protocol, environmental conditions, and patient characteristics are not clearly understood, the prescription could be inaccurate. The results of this review will help to clarify the relationship between RPE and the physiological responses to exercise. This information would be very useful to clinicians to evaluate and prescribe correctly exercise for pathological populations.

In addition, the results of this review will identify what study features have been only minimally investigated and are in need of further investigation. This information can then be used to help direct future research.

Questions that Guided this Study

1. What are the overall average weighted correlations between RPE and the physiological measures of heart rate (HR), ventilation minute volume (V_E), respiration rate (RR), oxygen uptake (VO_2) and blood lactate?

2. Are the correlations for each relationship homogeneous?

3. Do any of the following features of studies influence any of the five relationships listed in Question 1? The study features are:

   a. Type of RPE scale
   b. Mode of exercise
   c. Type of exercise protocol
   d. Subject sex
   e. Subject fitness level or activity level

Delimitations

This study was delimited to studies which provided a Pearson correlation coefficient between RPE and one or more of the following physiological measures: HR, VO_2, V_E, RR, or blood lactate. The subject population was limited to those who were free of muscular and cardiovascular disease because the types of physical restrictions, such as coronary insufficiency, arterial hypertension, or rheumatoid arthritis that had been considered by researchers, were too specific to be grouped together and too few to be considered separately. The types of exercise were limited to either bicycle riding, treadmill running, or track running. Other types of exercise considered were too few to be examined in relationship to moderator variables.

Definitions

The following definitions apply to this investigation:

1. <u>Exercise protocol</u>: The format which dictates whether exercise is continuous, intermittent, progressive, or random.

2. <u>Meta-analysis</u>: The statistical analysis of findings of studies with a common theoretical and statistical base.

3. Perceived exertion: The perception of physical work during exercise.

4. Physiological cues: Measures of biological responses to physical exercise, for example, HR.

5. Ratings of perceived exertion: A scale to numerically measure the perception of physical exertion.

6. Study features: The distinguishing variables within a study which make it unique, for example, subject sex.

Limitations

This study was limited by those studies which did not provide the statistics needed for meta-analysis procedures. In the RPE-HR relationship, not all correlations could be regarded legitimately as independent of each other. However, to avoid loss of information about important within study differences (e.g., differences in exercise modes and protocol), all of these correlations were included. Conservatism must, therefore, be used in interpreting these results.

CHAPTER II

NARRATIVE REVIEW OF LITERATURE

Perceptual responses have long been considered an important part of physical performance. Morgan (1973) stated that what an individual thinks he is doing, rather than what he is doing, is a valuable tool in understanding human performance. However, subjective perceptions are difficult to interpret because they are hard to define and to measure quantifiably. The core of the perceived exertion literature centers on defining perceived exertion, measuring it, and relating it to primary physiological cues. Perceived exertion and its relationship to physiological cues has also been examined under modified conditions of exercise. This chapter reviews the definition and measurement of perceived exertion, the relationship between physiological cues and perceived exertion ratings, and the unique study conditions that may alter these relationships. This chapter also reviews the definition and techniques of meta-analysis.

Defining Perceived Exertion

Borg (1962a) defined perceptual effort as a combination of both general feelings of fatigue originating from the cardiorespiratory system, and specific sensations from the muscles, joints, and skin. Borg and Noble (1974) regarded these cues as a "Gestalt" of numerous perceptual sensations that are a response to physical exertion. When healthy persons performed short-time work (less than one minute) on the bicycle ergometer, Borg (1962a) encouraged them to concentrate on sensations of stress from working skeletal muscles. In long durational work, the subjects were encouraged to perceive exertion in terms of shortness of breath or rapid heart beats. Borg suggested a distinction among perceptual responses depending on the duration of exercise, but he did not categorize the subjective symptoms according to different physiological cues.

Ekblom and Goldbarg (1971) were the first to suggest perceived exertion could be differentiated. They believed perceptions of physical work were based on two categories of physiological measures originating from sensations received from different bodily centers: (a) local factors which are feelings associated with strain in exercising muscles and joints, and (b) central factors which are feelings associated with physiological activity in the cardiopulmonary system. The feelings of strain in exercising muscles is quantifiably measured by lactate levels in the blood stream or in the muscle itself. The collection of muscle lactate levels is a painful process, therefore, the majority of researches use blood lactate levels to measures local factor involvement in physical exercise. The physiological activity in the cardiopulmonary system is measured quantifiably using heart rate (HR), oxygen uptake ($\dot{V}O_2$), respiration rate (RR) and ventilation minute volume (V_E). Pandolf (1978) supported this two-factor approach and suggested that when a particular physiological cue was the predominant physical response to exercise, it became the primary source of perception of exertion. Mihevic (1981) agreed with this contention and believed the differing perceptions were thereby related to specific variables, such as exercise intensity, modality, and protocol.

The ability to consciously monitor physiological cues is another part of the definition of perceived exertion. Noble et al. (1973b) hypothesized that perceptual responses to exertion were not the result of direct physiological changes, but were the result of indirect sensations caused by physiological changes. Morgan and Pollock (1977) found that elite distance runners were able to monitor these sensations and believed this technique was the base of the perception of effort. Mihevic (1981) believed the degree to which one is consciously aware of physiological changes affects the perception of effort. Unfortunately, indirect sensations of input from direct physiological changes is not clearly understood. However, various methods to measure perceived exertion have attempted to clarify the relationship between physiological measures and perceived exertion.

Techniques of Measurement

Ratio Methods

Psychological techniques of measurement were first used by Borg and Dahlstrom (1960) to determine perceived exertion during short-time work. They used a ratio method called "halving" to achieve a power function that could explain the relationship between physical and perceptual responses to exercise. This method required the subject to exercise at a specified level on a bicycle ergometer for less than one minute. The subject then had to adjust the level of exercise to what he perceived to be one-half of the original level. If the perceived estimate deviated above the physical half, the power function would be greater than one; if the estimate were below, the power function would be less than one. Borg and Dahlstrom's results showed that perceived effort increased above the actual physical effort. This power function was, therefore, found to be 1.6.

Borg (1962a) supported these earlier findings when he tested subjects in long-durational work. In this type of work, the subjects used a ratio method called magnitude estimation. This technique required the subjects to select a number, rather than readjust the level of work, to represent a current work load. When the load increased or decreased from the standard work level, the subjects picked a number relative to the first number to represent their perceptions of the physical change in work.

Many investigators used this method to measure perceptual effort. Stevens and Mack (1959) and Cain and Stevens (1971) used magnitude estimation to establish a relationship between the perceptual and physical magnitude of static and phasic handgrip force. Cafarelli (1977) used this technique to distinguish whether a subject used specific physiological type inputs during different bicycle ergometer work loads. Moffatt and Stamford (1978) used magnitude estimation to compare sex differences in progressively increased pedal rate and resistance on a bicycle ergometer. All these studies found positively accelerating power functions between 1.4 and 1.7. These power functions supported Borg's original power function of 1.6.

Both of these ratio methods established a positive relationship between the physical and perceptual increases in work load. However, there was a drawback to these techniques. They did not allow for interindividual comparisons. The estimated ratios represented only one individual's perception of a given work load. There was no standard perceptual scale developed from the ratios. Therefore, perceptions from a group of subjects could not be compared.

Scale Methods

To overcome the inability to make interindividual comparisons, Borg (1962b) developed a standard scale that would rate the perception of physical work. He believed a standard range of perceptual responses could be constructed from the perceptual estimations of many individuals. These perceptual responses were then compared to various physiological responses to the same exercise bout (Borg, 1961). From this comparison, Borg (1962b) constructed a numerical scale which illustrated the psychophysiological response to work on a bicycle ergometer. He used a scale that ranged from 1 to 21. If the subject chose a "9" following one level of exercise, and a "12" following a second level of exercise, the first response would mean the first exercise bout was perceived less strenuous than the second exercise bout.

Borg used phrases at equidistant intervals throughout the scale to give a base to the numerical scale. This scale is referred to as the 21-point scale which is illustrated in Table 1.

Borg and his associates (Borg & Linderholm, 1967, 1970; Borg, 1973) used this 21-point scale in various bicycle testing situations. They found these perceptual ratings correlated significantly with the HR responses to exercise. The correlations calculated by comparing HR responses and RPE at each level of exercise of a progressive continuous protocol ranged from .80 to .90.

Since HR correlated so well with the perceptual scale, Borg (1970) redesigned the scale to increase linearly with HR response to exercise. This scale ranged from 6 to 20, which parallels the HR responses which range from 60 to 200 bpm. Phrases were placed throughout the scale to illustrate the scale's linear progression. This scale is referred to as the 15-point scale which is in illustrated Table 2. When either the 21-point or 15-point scale was used to measure perceived exertion, the responses were referred to as ratings of perceived exertion (RPE).

The 15-point scale has demonstrated validity and reliability using random and progressive work loads (Skinner, Hutsler, Bergsteimova, & Buskirk, 1973b). In

Table 1

21 Point Scale

1	
2	
3	Extremely light
4	
5	Very, very light
6	
7	Very light
8	
9	Light
10	
11	Neither light nor heavy
12	
13	Heavy
14	
15	Very heavy
16	
17	Very, very heavy
18	
19	Extremely heavy
20	
21	

Note: From "Comparison of two rating scales in the estimation of perceived exertion in a pulse-conducted exercise test" by M. Arstila, H. Wendelin, I. Vuurl, & I. Valimaki, 1974, Ergonomics, 17, p. 578.

Table 2

15-Point Scale

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat light
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Note. From "Advances in the Study and Application of Perceived Exertion" by K. B. Pandolf, 1983, *Exercise and Sport Science Reviews*, *50*, p. 128.

addition, Ulmer, Janz, and Lollgen (1977) tested 10 athletes and found close correlations of perceptual ratings to HR (*r*=.88), and perceptual ratings to work (*r*=.93). Stamford (1976) determined the reliability of this scale under a variety of exercise modes (walking, jogging, bicycling, and stool stepping). Stamford's results indicated the scale was a sensitive and reliable measure of perceptual exertion.

Borg (1982), however, cautioned that the relationship between HR values and the 15-point scale could not be taken literally because HR could change in response to age, exercise mode, environment, and feelings of anxiety. Mihevic (1981), Ekblom and Goldbarg (1971), and others (e.g., Allen & Pandolf, 1977; Morgan, 1973; Pandolf, 1978; Skinner et al., 1973a) found that these factors affected the correlational strength between HR values and RPE. Pandolf (1983) suggested that the 15-point scale be used in applied studies to measure perceptual responses of individuals of specific age groups to a specific exercise and protocol.

Another scale developed to measure interindividual perceptual responses to work was a 9-point scale developed by Noble, Robertson, and McBurney (cited in Borg, 1973). The numbers in the scale ranged from 1 to 9. Verbal expressions were attached to the scale for clarification. The expression "not at all stressful" was attached to the Number 2, and the expression "very, very stressful" was attached to the number 8. This scale is illustrated in Table 3.

Borg (1982) compared this scale with his first 21-point scale and found a correlation of .92. Robertson, Gillespie, Hiatt, and Rose (1977) used the 9-point graded scale to measure perceptual responses among individuals who augment their perceptions of physical work and individuals who reduce their perceptions of such work. The following year Robertson, Gillespie, McCarthy, and Rose (1978) used this scale to compare the perceptual

Table 3

9-Point Scale

1	
2	Not at all stressful
3	
4	
5	
6	
7	
8	Very, very stressful
9	

Note: From "Differentiated perceptions of exertion: Part I. Mode of integration of regional signals" by Robert J. Robertson, Robert L. Gillespie, Dean McCarthy, and Kenneth D. Rose, 1979a, Perceptual and Motor Skills, 49, p. 685.

responses of performers who dissociate from their exercise with performers who associate with their exercise to the same work load criterion. In both studies, they found no significant difference between the subject groups identified. Their conclusions were that differences in psychological functioning did not account for individual differences in perceptual response during muscular exertion.

Ratio-Based Category Scale Method

Up to this point, the category scales (21-point scale, the 15-point scale, and 9-point scale) have allowed interindividual comparisons to a specific type of exercise. In order to compare interindividual responses across different exercise modalities, Borg, Holmgren, & Lindblad (1981) constructed a ratio-based category scale. The numbers in this scale ranged from 0 to 10 and were accompanied by verbal expressions. The expressions were arranged on the scale by the halving technique. For example, if a "6" were given the expression "strong," a "3" would be given an expression that represents one-half the work intensity, such as "moderate." The verbal expressions were, therefore, anchored to the scale according to ratio properties. This scale is referred to as the 10-point category-ratio scale and is illustrated in Table 4.

Table 4

New Category Ratio Scale

0	Nothing at all
0.5	Very, very weak (not noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Very, very strong (almost max)
.	
.	
.	Maximal

Note: From "Psychophysical bases of perceived exertion" by Borg, 1982, Medicine and Science in Sports and Exercise, 14, p. 380.

This 10-point category-ratio scale has been compared to both physiological and perceptual measures of physical exertion. Noble, Borg, Jacobs, Ceci, and Kaiser (1983) found a high correlation between perceptual ratings determined by the category-ratio scale and both blood and muscle lactates. Borg (1982) compared the 15-point scale with the new category-ratio scale, and found the ratio-based scale would be most appropriate in clinical situations where ratio properties would be suitable for determining subjective symptoms, such as aches and pains in the joints. The 15-point scale is more suitable for applied exercise testing where specific exercise protocols are used to predict and prescribe exercise intensities in sports and rehabilitative situations.

Throughout the development of methods to measure perceived exertion, HR was the physiological measure most often compared to RPE. Physiologists have continued to compare RPE with other physiological measures to understand the relationship between perceptual and physiological responses to exercise. To conduct their research, investigators have used the suggestion made by Ekblom and Goldbarg (1971) to divide physiological measures into central and local factor groups.

Central and Local Factor Influence on RPE

One theoretical concept pertaining to physiological influences on RPE is that physiological cues can originate from local or central factors. Ekblom and Goldbarg (1971) manipulated HR response to test the relationship between HR and RPE. They found that when the beta blocking drug, propranolol was administered, an individual could still perceive physical work using physiological cues other than HR. They based this speculation on responses to different exercise modes. When work involved small muscle groups, cues from the periphery, some of which are measured by blood lactate, seemed dominant indicators of RPE. When work involved large muscle groups, cues from the central system, such as HR or $\dot{V}O_2$, seemed dominant indicators of RPE.

Other researchers have provided support for Ekblom and Goldbarg's two-factor approach (Cafarelli & Noble, 1976; Pandolf, Burse, & Goldman, 1975). Pandolf and his colleagues (1975) designed an experimental model to study this approach. They used a technique called differentiated ratings of perceived exertion. The subjects were told to concentrate on either specific sensations of muscle strain, specific sensations of heavy breathing and faster HR, or an integration of both sensation types. During the exercise bouts, the subjects rated their perceptual responses to each of the categories using the 15-point RPE scale. Results indicated the two differentiated ratings were related to specific exercise modes. Local factors appeared to be the dominant indicators of perceived exertion during bicycling, and central factors appeared to be the dominant indicators during treadmill walking and running. Cafarelli and Noble (1976) also found that subjects rated local effort as more intense during bicycling when the differentiated method was used to measure perceived exertion.

Physiologists have continued to test the relationship of RPE and central and/or local physiological cues to determine their relationships across testing circumstances. Ekblom, Lovgren, Alderin, Fridstrom, and Satterstrom (1975) physically trained patients with rheumatoid arthritis. These patients were asked to differentially rate their perceptual response to physical exercise during the weeks of their training. Results indicated that both locally- and centrally-based perceptions decreased significantly in response to training. Gamberale (1972) found that subjects could differentiate between local and overall physiological changes when they were asked to perceive specific or overall sensations of exercise. Finally, Robertson et al. (1979a) used the differentiated technique with the 9-point category scale to evaluate sub-maximal bicycle ergometer exercise. Their results indicated that the overall RPE was significantly lower than the specific leg rating, but significantly higher than the specific chest or breathing rating.

Central Factors

The physiological cues that investigators consider to be centrally located are HR, ventilation minute volume (V_E), respiration rate (RR), and oxygen uptake ($\dot{V}O_2$) (Mihevic, 1981; Pandolf, 1978; Robertson, 1982). Findings both support and dispute a positive relationship of each of these cues to RPE.

<u>The Relationship between HR and RPE</u>. Most of the support for a positive relationship between HR and RPE was based on Borg's (1962a, 1962b) correlational findings. Skinner et al. (1973a) found consistent data supporting a positive relationship across exercise modes (bicycle and treadmill) of similar duration. Stamford (1976) reported high correlations between HR and RPE across exercise protocols (progressive and randomly ordered). Edwards, Melcher, Hesser, Wigertz, and Ekelund (1972) also found high correlations between HR and RPE across different exercise protocols (intermittent and continuous). Holmer, Kindblom, and Nordsstrom (1978) used the ratio estimation method to measure perception of work and found the power function remained between 1.6 and 1.7 for central-type factors, despite the working muscle group. Other studies have also supported the positive significant relationship between RPE and HR during various exercise bouts (Bar-Or, Skinner, Buskirk, & Borg, 1972; Gamberale, 1972; Kay & Shephard, 1969; Sargeant & Davies, 1973).

There is also research showing that the linear relationship between HR and RPE deteriorated when HR was manipulated by environmental and pharmacological treatments. Studies have shown that heat induced circulatory strain reduced the association between HR and

RPE (Kamon, Pandolf, & Cafarelli, 1974; Pandolf, Cafarelli, Noble, & Metz, 1972); that a change in exercise mode, such as from walking to running altered the relationship between HR and RPE (Noble, Metz, Pandolf, Bell, Cafarelli, & Sime 1973); and that propranolol modified the relationship of HR and RPE (Davies & Sargeant, 1979). Davies and Sargeant modified the effect of HR by injecting subjects with propranolol. Their results indicated HR had no significant relationship with RPE under these conditions during short-time work. They further concluded that HR was not an important factor underlying the perception of effort. Other studies have also disputed the positive HR and RPE relationship (Albert & Williams, 1975; Allen & Pandolf, 1972; Ekblom & Goldbarg, 1971; Hendriksson, Knuttgen, & Bonde-Peterson, 1972; Jackson, Dishman, Croix, Patton, & Weinberg, 1981; Martin, 1981; Noble, Maresh, Allison, & Drash, 1979). These researchers found that when either the physiological measure (HR) or the psychological measure (RPE) was manipulated by drugs or posthypnotic suggestion, only one of the two measures was altered which destroyed positive relationship.

The Relationship Between V_E and RPE and RR and RPE. Sensations, such as breathlessness, are consciously monitored by afferent nervous system signals (Edwards et al., 1972; Robertson, 1982). The work of Baker and

Tenney (1970) suggested that an individual receives sensory information from the chest wall. The relationship of RPE and V_E and RPE and RR have been examined by Kamon, Pandolf, and Cafarelli (1974) in neutral and heated conditions. Results indicated there were significant positive correlations between RPE and V_E and RPE and RR across temperature changes. Kamon et al. also concluded that sensory inputs from lung and chest receptors may be related to RPE. Pandolf et al. (1972) correlated RPE with V_E, and RR responses to bicycle ergometer work in neutral and hot-dry environments. Their results revealed that the relationship remained significant regardless of the temperature change. Sargeant & Davies (1973) also tested subjects on the bicycle ergometer and found RPE were closely associated to V_E.

Findings that dispute the relationship between V_E and RPE and RR and RPE have also been documented. Stamford and Noble (1974) tested subjects on a bicycle ergometer on a continuous and intermittent protocol. Their results indicated that compared to other physiological factors, V_E was not significantly related to RPE. Allen and Pandolf (1977) had their subjects breathe hyperoxic mixtures during two submaximal work loads on the treadmill to test the relationship between

RPE and V_E, and between RPE and RR. They found that V_E and RR were not significantly related to RPE. Cafarelli and Noble (1976) induced a hyperventilative state during exercise to manipulate V_E. Their results indicated V_E had no significant relationship to RPE at low levels of work. Edwards et al. (1972) and Robertson (1982) found the same result between V_E and RPE.

The Relationship Between $\dot{V}O_2$ and RPE. A third central physiological measure is $\dot{V}O_2$. Robertson (1982) and Mihevic (1981) have stated that $\dot{V}O_2$ does not seem to be monitored directly, however, researchers have compiled data supporting a relationship between $\dot{V}O_2$ and RPE. Sargeant and Davies (1973) found high correlations between RPE and body weight adjusted or relative $\dot{V}O_2$ (r=.76-.88) during maximal and submaximal work on a bicycle ergometer. Skinner et al. (1973b) found relative $\dot{V}O_2$ was more strongly related to RPE than absolute (nonbody weight adjusted) $\dot{V}O_2$ on treadmill work. In response to training, they found that both RPE and relative $\dot{V}O_2$ at a given submaximal load were lowered, but their relationship remained. Cafarelli (1977) found $\dot{V}O_2$ was significantly related to RPE on 4 minute bicycle ergometer exercise bout, and Horstman et al. (1979) found a significant relationship across temperature changes in the testing environment.

Other studies revealed a nonsignificant relationship between RPE and $\dot{V}O_2$. Carfarelli (1978) and Pandolf (1977) found $\dot{V}O_2$ was not a primary physiological factor related to RPE. In the evaluation of positive and negative work in climbing a laddermill, Pandolf, Kamon, and Noble (1978) found $\dot{V}O_2$ was not a dominant factor involved in RPE. Lollgen, Graham, and Sjogaard (1980) found the RPE increased proportionately with $\dot{V}O_2$ only at high speeds of limb movement on the bicycle ergometer. They concluded the relationship between $\dot{V}O_2$ and RPE was not significant. Pandolf (1978) and Ulmer et al. (1977) found the same results. Martin (1981) also found RPE and $\dot{V}O_2$ responses to exercise were unrelated after acute sleep loss.

Local Factors

Physiologists have also found both supporting and disputing evidence concerning the positive relationship between RPE and local physiological responses to physical effort. Ekblom and Goldbarg (1971) described local factors as feelings of strain in the exercising muscles. Mihevic (1981) defined it as muscle and blood lactates, Golgi tendon activity, and muscle, joint, and skin sensations as locally based physiological cues. Pandolf (1983), however, cautioned that lactates were the only quantifiable local physiological cues.

<u>The Relationship Between Blood Lactates and RPE</u>. Support for a relationship between RPE and blood lactate has been equivocal. Some studies have found significant relationships between RPE and blood lactate (Allen & Pandolf, 1977; Edwards et al., 1972; Ekblom & Goldbarg, 1971; Gamberale, 1972; Morgan & Pollack, 1977; Pederson & Welch, 1977). For instance, Ekblom and Goldbarg (1971) found that RPE at a given blood lactate concentration remained the same for both bicycle and treadmill work. Morgan and Pollack (1977) also found a significant relationship between RPE and blood lactate on the treadmill, and Gamberale (1972) found a significant relationship across exercise modes (wheelbarrow pushing, weightlifting, and bicycle riding).

Mihevic (1981), however, believed the relationship between blood lactate concentrations and RPE depended on the intensity of physical effort. At high exercise intensities lactate was related to RPE, but at lower levels of physical exertion, the relationship was nonsignificant. Mihevic also indicated that mechanisms acting as mediators between blood or muscle lactate levels and perceptual sensations have not been identified.

In addition, other researchers have found no correlational relationship between changes in blood lactate concentrations and RPE (Kay & Shepard, 1969; Lollgen et al., 1980; Pandolf, 1978; Stamford & Noble, 1974).

One possibility for the lack of correlational strength between perceived exertion and blood lactate is the time lag between production of lactate by the muscle and its subsequent appearance in the blood (Mihevic, 1981). Studies, however, have shown that blood lactates taken immediately after exercise (Edwards et al., 1972; Gamerale, 1972) and three minutes following exercise (Peterson & Welch, 1977) yield similar correlational results.

Other proposed local cues that may be related to RPE are kinesthetic cues, such as propioceptor feedback, Golgi tendon activity, and general muscle sensations. Most of the studies that investigated the relationship of kinesthetic cues to RPE did so by varying pedal frequencies on the bicycle ergometer and comparing perceptual responses to different exercise modalities. Pandolf et al. (1973) and Pandolf and Noble (1973) found that with varying pedal speeds, sensations particular to the working muscles seemed to be related to RPE. The latter study used the differentiated method of attaining RPE. Robertson et al. (1979a), and Stamford and Noble (1974) tested various speeds on the bicycle ergometer and

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found that sensations of muscle fatigue were used to rate perceptual effort.

In summary, many physiological cues appear to be related to RPE. Several researchers (Borg & Noble, 1974; Pandolf, 1978) believe local physiological cues are more highly related to perceptual responses when differential RPE are used. Robertson (1982) concluded that central factors act as amplifiers for local factor sensations during aerobic work. He suggested that local signals are more highly related to RPE at all exercise levels, but ventilatory signals become more highly related at high levels of exercise intensities which require large amounts of oxygen intake. Mihevic (1981), however, suggested that local or central factors or physiological measures in general cannot be compared to perceptual measures without considering the modifying study features that occur during exercise. Such features include exercise intensity, duration, and modality. Mihevic believed these variables could complicate the relationship between physiological measures and RPE. Other features, such as environmental factors and subject age, are also believed to have an impact on the perception of effort (Pandolf, 1978). These factors are discussed in the following section.

Modifying Variables

Subject Age and Sex Variables

Age differences among subjects tested in RPE have been investigated by researchers (Bar-Or, 1977; Borg & Linderholm, 1967). Borg and Linderholm (1967) tested male subjects ranging in age from 18 to 79 years on a graded bicycle ergometer test. Results indicated that "exercise at a given pulse rate is perceived to be heavier by old subjects than by young ones (p. 203)." Bar-Or (1977) assembled the results of eight research projects that had tested the relationship of perceptual ratings and physiological strain in age groups of male subjects ranging from 7 to 68 years. His results were consistent with Borg and Linderholm: Older men perceived a given exercise to be higher than younger men. Bar-Or found significant differences between boys and men.

Sex differences among subjects have also been investigated (Arstila, Antila, Wendelin, Vuroi, & Valimaki, 1977; Komi & Karppi, 1977; Stephenson, Kolka, & Wilkerson, 1982). Arstila et al. tested the effect of age and sex on the perception of exertion. They tested three men and three women ranging in age from 38 to 60 years on a progressive bicycle ergometer protocol. Results showed that the relationship between RPE and HR was better for men than women, and with an increase in age, there was an increase in RPE at a given work load. However, Komi and Karppi (1977) tested male and female monozygous and dizygous twins to investigate genetic variations in perceived exertion and HR during bicycle ergometer work and found the relationship between HR and RPE was not influenced by sex.

Subject Fitness and Activity Levels

Activity level, as a function of age, was also considered by investigators. (Bacharach, 1983; Bar-Or et al., 1972; Ekblom & Goldbarg, 1971; Milhevic, 1983; Morgan, 1973; Patton, Morgan, & Vogel, 1977; Skinner, Borg, & Buskirk, 1969). Most investigators found no change in the relationship between RPE and physiological cues as a function of activity level (Bar-Or et al., 1972; Mihevic, 1983; Morgan, 1973; Patton et al., 1977; Skinner et al., 1969). Mihevic concluded from her study that perception of exertion when measured by the 15-point Borg scale did not discriminate between groups of subjects ranging in fitness level during short-term exercise at low and moderate levels of work. Morgan (1973) found the same results when he tested Olympic-ranked wrestlers and contenders in submaximal work. However, when Bacharach (1983) tested college-aged females with varying levels of cardiovascular fitness on

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the bicycle ergometer and treadmill, results showed that RPE from subjects in better cardiovascular condition were more highly related to the physiological cues measured. Patton et al. (1977) compared RPE and HR in two groups of military personnel differing in normal activity level. They found that no difference existed in RPE between the groups in a six-minute run; but when they tested these same two groups of men after a six-month endurance program, results indicated that both groups had significantly lowered HR and RPE throughout the run when compared to their pretraining measures. They concluded that the intensity of absolute work did not differ between groups of different fitness levels; however, RPE and HR could be significantly lowered following physical training.

Studies investigating the effects of the above study features on the relationship between RPE and various physiological measures present equivocal results. When age was considered, it appeared the older the subject, the harder the activity was perceived. But does this finding influence the relationship between RPE and a specific physiological measure? When sex was considered, one study found significant differences, two others did not. However, can these studies' results be compared; did these studies use similar testing situations, such as the same protocol of exercise or the same age range of subjects? When subject fitness level was considered, was it measured the same way in each study? These questions are important when results are compiled to investigate whether specific study features modify overall study results of the relationship between RPE and physiological measures. The use of meta-analysis can help to objectively analyze the results of these various studies and to reveal any possible influences from study features.

An Overview of Meta-Analysis

Meta-analysis is a series of procedures which quantify, integrate, and analyze the results of a large number of research studies. It is a method of statistically combining measures of related study outcomes, but has been infrequently used in the sport and exercise science literature (Crews & Landers, 1987; Feltz & Landers, 1983; Sparling, 1980; Thomas & French, 1985, 1986; Zung, Weltman, Glass, & Mood, 1983). The technique of meta-analysis was first proposed by Glass (1976). Glass defined meta-analysis as "a rigorous alternative to the casual, narrative discussions of research studies which typify our attempts to make sense of the rapidly expanding research literature" (1976, p. 3). The goal of a meta-analysis is to analyze the variations in study findings in much the same way that data in primary research are analyzed. Questions concerning the effects of differences in study design or treatment implementation on overall study results are addressed empirically rather than narratively. Therefore, one can avoid the practice of eliminating studies deficient in design, thereby basing the conclusions of the review on a reduced number of observations (Jackson, 1978). Although meta-analysis could be just a thoughtless application of statistical summaries to the results of studies of questionable quality, Cooper (1984) outlined the typical steps taken to conduct a meta-analysis. These steps enable researchers to take a more rigorous and systematic approach to reviewing research.

The Stages of Meta-Analysis

Problem Formation. In this first step, research questions are outlined to guide the research review. The questions are those that address certain conceptual and operational definitions within the research constructs. In this analysis, the question that arose was: Do various study features modify the strength of the relationship of RPE and specific physiological responses to exercise?

Data Collection. The second step is to identify and collect studies which pertain to the specified area of research. The studies considered for this analysis tested for RPE during physical exercise and compared these ratings to selected physiological responses to exercise.

Data Evaluation. This stage involves the accumulation of study results and the "coding" of study features which may affect or explain various patterns of study outcomes. Quantitative components of study outcomes, like degree of relationship between RPE and a physiological measure, are computed. Subject features, the treatments, and the context of the study are compiled using a numerical coding design. The problem formation step provides guidance about which features should be included in the analysis. All pertinent features must be noted from each study in order to examine possible explanations for incongruencies among study results.

Data Analysis and Interpretation. This step involves the selection and application of statistical procedures to draw inferences about the question outlined in Step 1. Different procedures are available for statistical analysis. The procedure chosen is based on the statistical format of the research studies.

Public Presentation of Results. This last step is the discussion of results. Assuming numerous features were considered across numerous studies, the results can be particularly exhausting. However, regardless of the length or amount of detail, all results should be discussed which may clarify or explain equivocal research results.

Measuring Study Findings

In meta-analysis the statistical integration of empirical studies requires that the study findings be on some common scale. These study findings are treated as the dependent variable in the data analysis stages of meta-analysis. Glass and his colleagues (Glass, McGaw, & Smith, 1981) have described three categories of methods for integrating study findings that have some common scale: significant test findings, standardized mean differences, and outcomes of correlational studies. Methods that make use of findings reported in the form of statistical significance test statistics or their associated probabilities include vote-counting procedures, where one simply counts the number of studies that show a significantly positive, negative, or nonsignificant relationship, and the combination of significance levels into a joint test of a null hypothesis. These methods have many limitations, however, especially if the number of studies is small.

Glass's (1976) popularization of the effect size, or standardized mean difference has been the most common method of aggregating and studying the variability of the results of experimental studies. Glass has defined effect size as the difference between the means of the experimental group and the control group divided by the control group standard deviation. Where research reports do not contain the means and standard deviations of the experimental conditions, effect sizes can be calculated using one of the formulas described by Glass and his colleagues (1981). The effect size, therefore, represents the difference between the means of the experimental and control groups relative to the amount of random variation within those groups.

In the meta-analysis of correlational studies, the correlation coefficients between two variables, such as RPE and HR are integrated. Glass et al. (1981) suggest that it matters little whether analysis of the correlations is carried out in the matrix of r_{xy}, r^2_{xy}, or Fisher's Z transformation of r_{xy}. However, in the present review, analyses were calculated with the Fisher's Z transformation of r_{xy} in order to normalize the data across studies.

Statistical Analyses for Effect-Size Data

Glass (1976) argued that effect sizes (correlations or proportions) could be treated as "typical" data and analyzed using familiar procedures (e.g., ANOVA regression). This approach is problematic, however. According to Hedges (1981) the effect-size "data" do not usually satisfy the homoscedasticity assumption required of standard statistical analyses.

Hedges (1981, 1982) and Hedges and Olkin (1983, 1985) proposed a new set of techniques and statistical tests specifically designed for the examination of effect-size data. These procedures involve a test for homogeneity to determine if all the studies are consistent with the model of a single underlying population effect size. If the studies are found not to be homogeneous, alternative statistical methods are used to explain, estimate, or identify the sources of variability in study results.

Summary

The definition of perceived exertion as the perceptual interpretation of physical exercise, comes from a combination of Borg's (1962a) "Gestalt" theory and Ekblom and Goldbarg's (1971) differentiation theory. Physiological measures centrally or locally based, provide information for the perception of exertion.

However, the degree of which one is consciously aware of physiological changes and the possible influence of such variables as exercise intensity, modality, and protocol, make the relationship between perceived exertion and physiological changes unclear.

The relationship between central and local physiological cues and RPE were considered across numerous study conditions in an attempt to clarify this relationship. The central physiological cues considered were HR, V_E, RR, and $\dot{V}O_2$. This narrative review found that the relationship between RPE and HR was positive across different exercise modes and exercise protocols. But the relationship was found to deteriorate when HR was manipulated by environmental and pharmacological treatment. The relationships between RPE and V_E and RPE and RR was found positive across environmental changes; however, the relationship between RPE and V_E deteriorated across different exercise protocols and the relationships of both RPE and V_E and RPE and RR were found not to be significant when manipulated by pharmacological treatments. Positive relationships between RPE and $\dot{V}O_2$ were found across different exercise protocols and testing environments. However,this relationship was not significant across different exercise modes.

The local physiological cue reviewed in this chapter was blood lactate. This physiological measure is the only quantifiable local cue. The relationship between RPE and blood lactate has been reported to be positive across exercise modes, but the relationship was found to deteriorate across different exercise protocols which dictated exercise intensity.

Specific study features were considered in this chapter as possible moderators of the relationship between RPE and physiological cues. RPE results were different across subject age, but equivocal results were reported for the affect of subject sex. This narrative review found no change in the relationship between RPE and physiological cues as a function of activity levels across the same exercise protocols. However, across different exercise protocols, differences arose between the relationship of RPE and HR. Also, in the studies reviewed across different cardiovascular fitness levels, the relationship between RPE and central physiological cues was altered.

Equivocal results were found between RPE and centrally- and locally-based physiological cues under different study conditions. Meta-analysis was suggested as a method that could provide a quantifiable interpretation of the magnitude of influence among the different potential modifying study conditions.

CHAPTER III

METHOD

The influence of modifying study features on the relationship between RPE and the specific physiological measures of heart rate (HR), ventilation minute volume (V_E), respiration rate (RR), oxygen consumption ($\dot{V}O_2$), and blood lactate was investigated using meta-analysis techniques. This chapter contains a description of the literature search procedures used to identify the collection of studies, the coding of study features, and the treatment of data.

The Collection of Studies

A literature search was conducted using manual and computer methods. The manual search was based on bibliographies from pertinent reviews (Borg & Noble, 1974; Mihevic, 1981; Pandolf, 1978, 1983). Three separate data base searches were used to identify additional studies and confirm studies previously identified manually. The Educational Resources Information Center (ERIC) data base was used to search the social science journals for published studies, dissertations, and theses. The PSYC data base was used to search the psychological abstracts for published studies, dissertations, and theses. The Excerpta Medica data base was used to search international biomedical journals for abstracts and citations of published studies. A list of keywords is contained in Appendix A.

From this search 79 studies were retrieved for initial consideration. Each article was then read, effect-size measures were extracted where sufficient data were provided, and relevant study features were coded. This procedure resulted in 23 studies for which effect sizes could be obtained. The 56 studies that were excluded from the meta-analysis either used methods to measure RPE other than the three scales considered for this review (11 studies), used exercise protocols other than the five considered (two studies), used an exercise mode other than the three considered (one study), used subject groups, such as cardiac rehabilitation patients not included in this review (six studies), did not statistically relate RPE to any physiological measures (three studies), or did not present the statistics needed to extract effect sizes (33 studies). A list of studies excluded from the meta-analysis is contained in Appendix B to help the reader judge the comprehensiveness and representativeness of the literature search (Hunter, Schmidt, & Jackson, 1982).

Coding of Study Features

Data selected for this meta-analysis were from studies which reported relationships of RPE and specific physiological measures under specific exercise conditions and using specific subject groups. Numerous study features were coded for the 23 samples in the final collection. Table 5 presents a list of the study features and their categories used in this review. Certain categories were excluded from analysis if there were fewer than three that were obtained.

Type of Physiological Measure

The physiological measures considered were heart rate (HR), ventilation minute volume (V_E), respiration rate (RR), oxygen consumption ($\dot{V}O_2$) and blood lactate. Nonquantifiable cues, such as proprioceptive activity, were excluded from the study.

Type of RPE Scale

Three types of RPE scales were considered for this meta-analysis: the 15-point scale (Borg, 1970), the 21-point scale (Borg, 1962), and the 9-point graded scale (Noble, Robertson, & McBurney, 1975). The category-ratio scale (Borg, 1981) was excluded from this study because only a single study had used it to measure RPE. Also excluded were studies which used ratio methods to measure

Table 5

Features of Studies

Study Feature	Categories of Study Features
Type of Physiological Measure	Heart Rate Ventilation Minute Volume Respiration Rate Oxygen Consumption Blood Lactate
Type of RPE Scale	15-point scale 21-point scale 9-point scale
Mode of Exercise	Bicycle Ergometer Treadmill Road/Track Running
Type of Exercise Protocol	Progressive--Continuous Progressive--Intermittent Random Intermittent One Level--Maximum Extertion One Level--Submax Extertion
Subject Sex	Male Female
Subject Fitness/ Activity Level	Sedentary Healthy--Nonactive Active Highly Fit

perception of work because these methods did not allow interindividual comparisons.

Type of Exercise

Three exercise modes were considered: cycling on the bicycle ergometer, walking or running on the treadmill, and running on a road or track. Exercise activities, such as hand-grip strength, were excluded because only two studies used these exercises too few to warrant their inclusion in this meta-analysis.

Type of Exercise Protocol

Five exercise protocols were considered. The progressive-continuous and progressive-intermittent protocols start with low levels of exercise and progress to more strenuous levels of exercise. In the progressive-continuous protocol subjects perform the exercise levels without rest between workloads. In the progressive-intermittent protocol subjects perform the exercise levels with rest periods between each workload. The random-intermittent protocol has a random, rather than a progressive, order of exercise levels with rest provided between each workload. The maximal exertion protocol remains at one exercise level. The subject continues to exercise at this level until she or he becomes physically exhausted. The submaximum exertion protocol also remains at one exercise level. The subject exercises at this level in a physical steady state for a specified period of time.

<u>Subject Sex</u>

Subject sex was included in this meta-analysis. Studies using female subjects, studies using male subjects, and studies using both male and female subjects were analyzed.

<u>Subject Fitness /Activity Level</u>

The aerobic fitness levels of subjects were included in the meta-analysis when the levels were measured by maximum oxygen uptake. The subjects' fitness levels were sometimes described by their activity levels and categorized as sedentary, healthy but nonactive, active, or high fit. Maximum oxygen uptake is a physiological measure which indicates how well an individual adapts aerobically to the increased metabolic needs of exercise. The higher the oxygen uptake, the more aerobically fit is the individual. The categorization by activity level is a subjective method of measuring an individual's fitness level.

Several other study features were coded and available for analysis. The number of subjects in each study and the lowest age, highest age, and the mean age were listed. The exercise levels, the increments between levels, and the length of each exercise level were listed by exercise mode. The bicycle ergometer exercise levels and the increments between these levels measured in kilograms per minute and in revolutions per minute were listed. The treadmill exercise levels and the increments between levels measured in miles per hour and percent grade were listed. The time per exercise level measured in seconds was listed. Also listed was time in seconds when the physiological measure and RPE measure were recorded at each exercise level.

Treatment of the Data

Definition and Computation of Effect Size

Every study included in this review used as the common statistic the Pearson correlation coefficient between RPE and one of the physiological measures. To normalize these values, the correlations were changed to *Z* scores using the Fisher "*r* to *Z*" transformation. *Z* scores were computed for as many distinct relationships between RPE and physiological measures as were examined in each study. Thus, a single study could provide any number of correlations.

The results of the studies (i.e., the *Z* scores) were then divided into five groups based on the pairing of RPE wit

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with specific physiological measures: (a) RPE and HR, (b) RPE and V_E, (c) RPE and RR, (d) RPE and $\dot{V}O_2$, and (e) RPE and blood lactate. These pairings are referred to as RPE-physiological (RPE-PM) relationships.

Model Fitting and Estimation

The analyses conducted in this review were based on Hedges' (1981, 1982) tests for fitting categorical models to effect sizes. Correlations representing each RPE-PM relationship were analyzed separately to test whether the data were reasonably consistent with the model of a single underlying population correlation. Hedges' test of homogeneity, $\underline{H}_T$, was used. The formula for $\underline{H}_T$ is:.

$$(N_i-3)(\underline{Z}_i, - \bar{\underline{Z}})^2 = \underline{H}_T$$

Each $\underline{Z}_i$ represents an individual correlation and the mean of the $\underline{Z}_i$'s represents the average correlation weighted by sample size. Larger $(\underline{Z}_i - \bar{\underline{Z}})$ differences indicates inconsistency among the studies. Each $\underline{N}_i$ is the sample size for the specific correlation, thus $\underline{N}_i-3$ is the variance of each $\underline{Z}$. The $\underline{H}_T$ statistic indicates whether the sample correlations seem more varied than would be expected on the basis of sampling variability. The $\underline{H}_T$ value is compared to a chi-square distribution with $\underline{K}$-1 degrees of freedom (where $\underline{K}$ = the number of correlations). If the $\underline{H}_T$ value for any RPE-PM relationship is less than the chi-square critical value, it is not significant and the correlations are considered homogeneous. This indicates that the correlations representing this RPE-PM relationship are similar regardless of features of the studies from which they were drawn, such as type of exercise or age of subjects.

If the test of homogeneity is significant, the correlations representing the RPE-PM relationship are not consistent and the average correlation value cannot be generalized across studies. When this occurred for one of the RPE-PM relationships, the correlations of RPE with that physiological measure were grouped by each of the following study features: (a) RPE scale type, (b) exercise mode, (c) exercise protocol, (d) subject sex, and (e) subject fitness level. Then an analogue to the analysis of variance was used to examine between group differences in correlations and homogeneity of correlations within groups. This analysis was conducted for each study feature. It determined whether any of these study features had a modifying effect on the correlations. ANOVA-like comparisons were used based on the relationship:

$$H_B = H_T - H_W$$

H_T represents the total homogeneity value across the correlations for each RPE-PM relationship. H_W represents total within-group homogeneity, that is, homogeneity within the categories for the study-feature grouping. $\underline{H}_B$ represents the difference between the total value of the RPE-PM relationship and the total within study-feature group $\underline{H}_W$ value. $\underline{H}_B$ was then compared to the chi-square table with values for the appropriate degrees of freedom found by the number of categories within a study feature group minus one. If $\underline{H}_B$ were larger than the chi-square statistic, the study feature had a modifying effect on the correlations.

If one of the study features, such as exercise mode, was found to have a significant modifying effect on the correlations of an RPE-PM relationship, such as RPE and HR, the test of homogeneity was conducted for each class of studies for the study feature. For example, for exercise mode, three class homogeneity values were calculated from the correlations of studies using the bicycle ergometer, the treadmill and track running. These category-wise $\underline{H}$ values sum together to equal the total $\underline{H}_W$ value described earlier. Each of these within-groups values was compared to the appropriate chi-square value to test for homogeneity. This process of analysis is presented in Figure 1.

If the H_W value was significant, it indicated that within a specific study feature, such as exercise protocol, the correlations remained heterogeneous. This

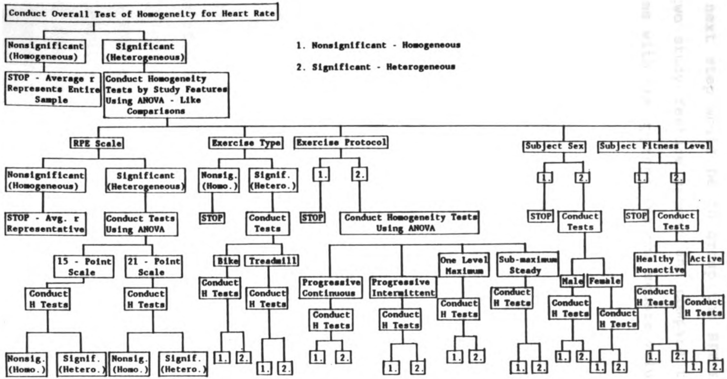

Figure 1.--Sample Process of Analysis for Tests of Homogeneity for the RPE-HR Relationship.

means other study features continued to modify the relationship between RPE and the physiological measure. The next step would be to group the RPE-PM correlations by two study feature groups and compare the resulting H values with the appropriate chi-square values.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this review was to determine whether various study features have a modifying effect upon the strength of the relationship of RPE and specific physiological responses to exercise through the use of meta-analysis procedures. The following questions guided this study:

1. What are the overall average weighted correlations between RPE and the physiological measures of HR, $\dot{V}_E$, RR, $\dot{V}O_2$, and blood lactate?

2. Are the correlations for each relationship homogeneous?

3. Are any of the five RPE-PM relationships influenced by the study features of type of RPE scale, mode of exercise, type of exercise protocol, subject sex, and subject fitness level?

This chapter includes a description and discussion of the results of this meta-analysis. The chapter is divided into results of the overall tests of homogeneity and results of the tests of study features for HR and RPE. A brief discussion of results has been included in each section with a general discussion included in the next chapter. All the statistical results are reported at the .05 level of significance unless otherwise specified.

From the 23 studies used in this meta-analysis, 79 correlations were obtained. The maximum number of correlations from any one source was 10 (Bar-Or, 1977). A summary of the characteristics for these 23 studies is presented in Table 6. Included in this table are the number of subjects in each study, subject sex, subject age, subject fitness level, type of RPE scale used, exercise modes, exercise protocol, and correlation coefficients.

Overall Test of Homogeneity

An overall test of homogeneity (Hedges, 1982) was conducted in each of the five RPE-PM relationships (RPE and HR, RPE and V_E, RPE and RR, RPE and $\dot{V}O_2$, and RPE and blood lactate) separately. Table 7 shows the summary of results of the analysis of each set of correlations.

The overall homogeneity test H_T value for the RPE and HR relationship was 171.41 which was compared to the chi-square value of 66.34 with K-1=49 degrees of freedom. The H_T value was greater than the chi-square value; therefore, the homogeneity test for the 50 correlations was significant. This implies that the correlations were not consistent across HR studies, and the average weighted

Table 6

Summary of Characteristics and Correlations for Perceived Exertion Studies

Study	N	RPE-PM Relationship	Sex	Age Lo	Age Hi	Age $\bar{X}$	$\dot{V}O_2$ Max	Fitness Level	RPE Scale	Exercise Type	Exercise Protocol	r
Allen & Pandolf (1977)	12	RPE & Blood Lactate	M			20	49		15-pt.	Treadmill	One Level Submax	.64
Arstila et al. (1974)	10	RPE + HR	M	29	47	39		Healthy	15-pt.	Bike Erg.	Prog. Cont.	.83
	15	RPE + HR	M	29	47	39		Healthy	15-pt.	Bike Erg.	Prog. Cont.	.87
	9	RPE + HR	M	29	47	39		Healthy	15-pt.	Bike Erg.	Prog. Cont.	.88
Bacharach (1984)	9	RPE + HR	F	20	30	26	46		15-pt.	Bike Erg.	Prog. Cont.	.64
	11	RPE + HR	F	19	26	21	33		15-pt.	Bike Erg.	Prog. Cont.	.65
Bar-Or (1977)	70	RPE + HR	M	07	10	08		Active	15-pt.	Bike Erg.	Prog. Cont.	.76
	189	RPE + HR	M	10	12	11		Active	15-pt.	Bike Erg.	Prog. Cont.	.79
	249	RPE + HR	M	13	14	14		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.79
	81	RPE + HR	M	16	17	17		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.88
	105	RPE + HR	M	18	21	20		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.70
	121	RPE + HR	M	22	25	24		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.75
	116	RPE + HR	M	26	30	28		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.68
	118	RPE + HR	M	31	35	33		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.61
	108	RPE + HR	M	36	46	41		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.67
	102	RPE + HR	M	50	68	59		Nonactive	15-pt.	Bike Erg.	Prog. Cont.	.60
Borg (1973)	69	RPE + HR	M	18	19			Military conscripts	15-pt.	Bike Erg.	One level-max	.62
	63	RPE + HR	M	18	19			Military conscripts	21-pt.	Bike Erg.	One level-max	.56
	43	RPE + HR	M	18	19			Military conscripts	15-pt.	Bike Erg.	Prog. Cont.	.72
	43	RPE + HR	M	18	19			Military conscripts	21-pt.	Bike Erg.	Prog. Cont.	.60
Butts (1982)	127	RPE + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.46
	127	RPE + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.46
	127	RPE + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.63
	127	RPE + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.74
	106	RPE + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.62
	43	REP + HR	F	13	18	16	51		15-pt.	Treadmill	Prog. Cont.	.25
Edwards et al. (1972)	3	RPE + HR	M	24	13	28			15-pt.	Bike Erg.	Prog. Cont.	.88
	3	RPE + HR	M	24	13	28			15-pt.	Bike Erg.	Prog. Inter.	.86
	3	RPE + V_E	M	24	13	28			15-pt.	Bike Erg.	Prog. Cont.	.94
	3	RPE + V_E	M	24	13	28			15-pt.	Bike Erg.	Prog. Inter.	.90
	3	RPE + Blood Lactate	M	24	13	28			15-pt.	Bike Erg.	Prog. Cont.	.77
	3	RPE + Blood Lactate	M	24	13	28			15-pt.	Bike Erg.	Prog. Inter.	.63
	3	RPE + VO_2	M	24	13	28			15-pt.	Bike Erg.	Prog. Cont.	.97
	3	RPE + VO_2	M	24	13	28			15-pt.	Bike Erg.	Prog. Inter.	.92
	3	RPE + RR	M	24	13	28			15-pt.	Bike Erg.	Prog. Cont.	.67

Table 6 cont.

Table 6 (Continued)

Study	N	RPE-PM Relationship	Sex	Age Low	Age Hi	Age $\bar{X}$	$\dot{V}O_2$ Max	Fitness Level	RPE Scale	Exercise Type	Exercise Protocol	r
Gaberale	12	RPE + HR	M	20	35	27		Nonathlete	15-pt.	Bike Erg.	Prog. Cont.	53
(1972	12	RPE + HR	M	20	35	27			15-pt.	Bike Erg.	Prog. Cont.	57
	12	RPE + HR	M	20	35	27		Nonathlete	15-pt.	Bike Erg.	Prog. Cont.	72
	12	RPE + HR	M	20	35	27		Nonathlete	15-pt.	Bike Erg.	Prog. Cont.	47
Gamberale & Homer (1977)	10	RPE + HR	M	27	37	32		Nonathlete	15-pt.	Bike Erg.	Prog. Cont.	41
Higg et al. (1981)	12	RPE + HR	F	19	23			Active	21-pt.	Treadmill	One-level submax	75
Jackson et al. (1981)	67	RPE + HR	M			21		Active	15-pt.	1.5 mile run	One-level max	16
Kamon et al.	10	RPE + HR	M	18	26	21	59		15-pt.	Bike Erg.	Prog. Cont.	48
(1974)	10	RPE + V_E	M	18	26	21	59		15-pt.	Bike Erg.	Prog. Cont.	77
	10	RPE + RR	M	18	26	21	59		15-pt.	Bike Erg.	Prog. Cont.	47
	10	RPE + VO_2	M	18	26	21	59		15-pt.	Bike Erg.	Prog. Cont.	52
Kay & Shepard (1969)	10	RPE + Blood lactate	M	20	51	30	43		15-pt.	Bike Erg.	Steady-submax	15
Kilbrom et al.	12	RPE + HR	F	19	31	24	37		15-pt.	Bike Erg.	Prog. Inter.	90
(1971)	8	RPE + HR	F	37	48	44	31		15-pt.	Bike Erg.	Prog. Inter.	88
	13	RPE + HR	F	51	64	56	27		15-pt.	Bike Erg.	Prog. Inter.	82
	10	RPE + HR	F	19	31	24	41		15-pt.	Bike Erg.	Prog. Inter.	87
	8	RPE + HR	F	37	48	44	35		15-pt.	Bike Erg.	Prog. Inter.	88
	12	RPE + HR	F	51	64	56	29		15-pt.	Bike Erg.	Prog. Inter.	80
	12	RPE + Blood Lactate	F	19	31	24	37		15-pt.	Bike Erg.	Prog. Inter.	89
	8	RPE + Blood Lactate	F	37	48	44	31		15-pt.	Bike Erg.	Prog. Inter.	72
	13	RPE + Blood Lactate	F	51	64	56	27		15-pt.	Bike Erg.	Prog. Inter.	75
	8	RPE + Blood Lactate	F	19	31	24	41		15-pt.	Bike Erg.	Prog. Inter.	62
	12	RPE + Blood lactate	F	37	48	44	35		15-pt.	Bike Erg.	Prog. Inter.	71
				51	64	56	29		15-pt.	Bike Erg.	Prog. Inter.	74

Table 6 cont.

Table 6 (Cotinued)

Study	N	RPE-PM Relationship	Sex	Age Low	Age Hi	Age $\bar{X}$	$\dot{V}O_2$ Max	Fitness Level	RPE Scale	Exercise Type	Exercise Protocol	r
Lollgen et.al (1977)	48	RPE + HR	M	23	35	29		Nonathlete	15-pt.	Bike Erg.	Random Intermit.	63
Morgan (1977)	27	RPE + HR	M	18	31	25	74		15-pt.	Treadmill	One Level Submax	43
	27	RPE + V_E	M	18	31	25	74		15-pt.	Treadmill	One Level Submax	52
	27	RPE + Blood Lactate	M	18	31	25	74		15-pt.	Treadmill	One Level Submax	61
Noble et al. (1973)	6	RPE + V_E	M	18	22	21	59		15-pt.	Bike Erg.	One Level Submax	56
	6	RPE + V_E	M	18	22	21	59		15-pt.	Bike Erg.	One Level Submax	75
	6	RPE + V_E	M	18	22	21	59		15-pt.	Bike Erg.	One Level Submax	56
	6	RPE + V_E	M	18	22	21	59		15-pt.	Bike Erg.	One Level Submax	68
Pandolf (1972)	10	RPE + V_E	M	18	26	21	58		15-pt.	Bike Erg.	One Level Submax	78
	10	RPE + RR	M	18	26	21	58		15-pt.	Bike Erg.	One Level Submax	60
Pedersen & Welch (1977)	6	RPE + HR	M	22	29	26		Nonathlete	15-pt.	Bike Erg.	Prog. Cont.	12
	6	RPE + HR	M	22	29	26			15-pt.	Bike Erg.	Prog. Cont.	03
	5	RPE + HR	M	22	29	26			15-pt.	Bike Erg.	Prog. Cont.	37
Sargeant & Davies (1974)	6	RPE + HR	M	24	39	31	44		15-pt.	Bike Erg.	Prog. Cont.	84
	6	RPE + VO_2	M	24	39	31	44		15-pt.	Bike Erg.	Prog. Cont.	87
	6	RPE + V_E	M	24	39	31	44		15-pt.	Bike Erg.	Prog. Cont.	90
Skinner et al. (1969)	26	RPE + HR	M	17	24	--		Mixed	15-pt.	Bike Erg.	Prog. Cont.	83
Stamford (1976)	36	RPE + HR	F	18	21	19		Sedentary	15-pt.	Treadmill	Prog. Cont.	41
Stephenson et al. (1982)	6	RPE + HR	F	19	47	26	43		9-pt.	Bike ERg.	One level submax	87

Note. Bike Erg. = Bike Ergometer
Prog. Cont. = Progressive continuous
Prog. Inter. = Progressive intermittent
Random Interm - Random intermittent

Table 7

RPE-PM Relationship Tests of Homogeneity

RPE-PM Relationship	*K*	*df*	Test of Homogeneity	χ^2	Average Correlation
RPE and HR	50	49	171.41*	66.34	.68
RPE and V_E	10	9	16.92	18.31	.66
RPE and RR	4	3	7.86	9.40	.54
RPE and $\dot{V}O_2$	4	3	5.99	7.80	.69
RPE and Blood Lactate	11	10	10.96	18.31	.64

*p < .05.

correlation value of .68 cannot be representative of all HR studies. A modifying influence from one or more of the study features may explain the variation in correlations. The heterogeneity of RPE-PM relationship did not seem surprising because the correlations ranged from .03 to .90. Furthermore, not all correlations of RPE and HR could be regarded legitimately as independent of each other. However, results were calculated under this assumption to allow the comparison of many interesting relationships within studies (Glass, 1977).

The average weighted correlation was .68, which was low in comparison to results in Borg's (1982) review of the literature. Borg reported that many of the correlations between RPE and HR ranged from .80 to .90 when HR ranges were compared to RPE using the 15-point scale. The difference may be attributed to the fact that Borg's correlations were based on data collected using primarily one population, exercise, and protocol (healthy males exercised on a bicycle ergometer using a progressive continuous protocol).

The overall homogeneity test $\underline{H}_T$ values for the four other RPE-PM relationships were less than their respective chi-square values, and were, therefore, not significant. These tests indicated the correlations were homogeneous and the average weighted correlation values for each relationship could be generalized across studies. These correlations were not more varied than would be expected on the basis of sampling variability. In other words, regardless of the study features within each study, the average correlations were representative of the respective relationships between RPE and the physiological measures compared.

For the relationship of RPE and V_E, the average weighted correlation of .66 represented correlations that ranged from .52 to .94. For studies of the RPE and RR relationship, the average weighted correlation of .54 represented correlations ranging from .47 to .67. The average weighted correlation of .69 represented a range of correlations from .52 to .97 for the RPE and $\dot{V}O_2$ relationship. And for the relationship of RPE and blood lactate, the average weighted correlation of .64 represented correlations ranging from .52 to .94. The four average correlations were considered representative of the respective RPE-PM relationships regardless of the correlation ranges within each RPE-PM group. The number of correlations for each of these last four RPE-PM relationships was considerably smaller than the number of correlations for the RPE and HR relationship. Also, the features of the studies within the four homogeneous RPE-PM relationships were similar. In general, the sample sizes were small, ranging from three to twelve. All studies but one used male subjects. The 15-point RPE scale was used in all studies and the bicycle ergometer was also used in all studies. The subjects' average ages ranged from 20 to 30 with only two sample groups in their 50's. All subjects' fitness levels were measured by VO_2max. With these similarities in study design, it does not seem surprising that studies of these four RPE-PM relationships are homogeneous results.

The Homogeneity Tests of Study Features for RPE and HR

To find an explanation for the heterogeneity of the 50 correlations within the RPE and HR relationship, the effects of the following study features were considered: type of RPE scale, mode of exercise, type of exercise protocol, subject sex, and subject fitness level. $\underline{H}$ values were calculated for each class within each study feature, and ANOVA-like comparisons were calculated for each study feature group to determine whether between-category differences existed, or equivalently whether each had a modifying effect on the overall RPE-PM relationship $\underline{H}_T$ value.

RPE Scale

The 50 correlations representing RPE and HR relationship were divided into categories by the type of

RPE scale used for each correlation. The 15-point scale was used for 46 correlations (r = .68), the 21-point scale was used for three correlations (r = .59), and the 9-point scale was used for one correlation (r = .87). H values were calculated for the 15-point and 21-point scale categories, and the H_T was zero for the 9-point scale category because there was only one correlation. H_B and H_W values were also calculated for the RPE-scale categories. Table 8 presents the summary results of the ANOVA-like comparison analysis.

The H_B value was less than the chi-square value, indicating the between-categories homogeneity test was not significant. Therefore, the type of RPE scale does not appear to have a modifying effect on the relationship between RPE and HR. Furthermore, the H_W value was significant, indicating that considerable variability remained within the RPE scale categories. This result suggests that other study features within the significant class groupings may continue to modify the correlational results between RPE and HR.

Exercise Mode

When the 50 RPE-HR correlations were grouped by mode of exercise, the bicycle ergometer was used for 40 correlations (r = .73), the treadmill was used for nine correlations (r = .57), and a 1.5 mile track run was used

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Table 8

Analysis of Variation in Correlations Between RPE and HR for Type of RPE Scale

Source of Variation	K	df	Homogeneity Test	Average Correlation
Total	50	49	H_T = 171.41*	0.68
Between RPE Scales	2	1	H_B = 3.17	--
Within RPE Scales	--	48	H_W = 168.24*	--
15-point scale	46	45	H = 167.33*	0.68
21-point scale	3	2	H = 5.99	0.59
9-point scale	1	--	H = 0.00*	0.87

*$p < .05$.

for one correlation (r = .16). The correlation representing the relationship between RPE and HR in the 1.5 run is considerably lower than the average weighted correlations for the bicycle ergometer and the treadmill. In their discussion, Jackson et al. (1981) speculated the reason the correlation was so low was due to the fact that the 1.5 mile run was not predominantly aerobic in nature. Therefore, the relationship between RPE and the aerobic HR measure was not high. H values were calculated for the bicycle ergometer and treadmill categories, but not for the 1.5 mile run because there was only one correlation. H_B and H_W values were also calculated. Table 9 summarizes the results of the ANOVA-like comparison analysis.

The results indicated that differences between the categories of exercise (represented by H_B) were significant. These results indicated that when the RPE-HR correlations were divided by exercise modes, the average correlations were significantly different. Thus, this result supports Pandolf's (1975) findings that RPE is dependent on exercise mode. However, the significance of the H_W value indicates that heterogeneity also occured within the categories. The average weighted correlation range for the bicycle ergometer exercise group was .03 to .97. The average weighted correlation range for the treadmill exercise group was .25 to 75. These ranges

Table 9

Analysis of Variation in Correlations Between RPE and HR for Type of Exercise.

Source of Variation	*K*	*df*	Homogeneity Test	Average Correlation
Total	50	49	H_T = 171.41*	0.68
Between Exercise Types	2	1	H_B = 70.58*	--
Within Exercise Types	--	48	H_W = 100.83*	--
Bicycle	40	39	H = 73.74*	0.73
Treadmill	9	8	H = 28.09*	0.57
Track	1	0	H = 0.00	0.16

*$p < .05$.

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ranges indicated a wide spread remained among the correlations when divided by exercise mode and therefore, other variables could be influencing the correlational relationships.

These other variables are study features that continue to influence the heterogeneity of these correlations when they were grouped by exercise mode. A study by Butts (1982) showed an average correlation of .53. The subjects in this study were "highly fit;" the average $\dot{V}O_2max$ was 51 ml/kg/min. They were exercised on a treadmill with a progressive continuous protocol. The type of exercise and protocol are common to the perceived exertion literature; however, the subject group is more physiologically elite than the common subject population used in this area. Perhaps this subject groups' RPE were different from other subject groups. Or, due to their high fitness level, the subject groups' HR response may be different. These may be an additional modifying study features when the correlations are divided by exercise mode.

A second study that used an unusual subject group was Stamford (1976). This subject group was described as "sedentary." They, too, were exercised on a treadmill with a progressive continuous protocol. The speed and percent grade of the treadmill protocol levels were dif

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different in the Butts study, but this difference was dictated by subject fitness level. The point to consider is, whether subject fitness levels continue to modify the relationship of RPE and HR when exercise mode (and exercise protocol) are held constant.

Exercise Protocol

When grouped by the type of exercise protocol, 36 correlations were based on a progressive-continuous protocol ($\underline{r}$ = .69), seven correlations were from studies using a progressive-intermittent protocol ($\underline{r}$ = .86), one correlation was calculated using a random intermittent protocol ($\underline{r}$ = .63), three correlations were based on one level to maximum exertion ($\underline{r}$ = .46), and three correlations were calculated using one level to submaximum exertion ($\underline{r}$ = .58). $\underline{H}$ values were determined for all protocols except random intermittent which was used for only one correlation. The ANOVA-like comparisons for the four types of exercise protocols are presented in Table 10. Results indicated the $\underline{H}_B$ value was significant; the categories of exercise protocols were significantly different from each other. However, the $\underline{H}_W$ value was also significant which indicated that within specific exercise protocol categories, the correlations remained heterogeneous. The $\underline{H}$ values for the progressive continuous protocol and one level to maximum exertion

Table 10

Analysis of Variation in Correlations Between RPE and HR for Type of Protocol

Source of Variation	*K*	*df*	Homogeneity Test	Average Correlation
Total	50	49	H_T = 171.41*	0.68
Between Protocol Types	4	3	H_B = 31.67*	--
Within Protocol Types	--	47	H_W = 139.74*	--
Prog. Cont.	36	35	*H* = 124.42*	0.69
Prog. Inter.	7	6	*H* = 0.89*	0.86
Random Inter.	1	0	*H* = 0.00	0.63
One level Max	3	2	*H* = 11.73*	0.46
Submax. Steady	3	2	*H* = 3.20*	0.58

*$p < .05$.

protocol showed these two categories remained heterogeneous. Other study features, therefore, continued to modify the relationship between RPE and HR.

From the studies whose correlations were included in these two categories of exercise protocols, the 95% confidence interval for two studies suggest that they were outliers. Bar-Or (1977) used a progressive continuous protocol to exercise subjects with an average age of 9.5 years on a bicycle ergometer. The exercise protocol and the type of exercise were common to the perceived exertion literature, but the average age of the subject group was younger than common subject groups used. The average correlation between RPE and HR was .78. Subjects ($\underline{M}$ = 16 years) in the Butts (1982) study were exercised on a treadmill using a progressive continuous protocol. Both studies used young subjects whose RPE scores were different from other adult subject groups which were tested using the same exercise protocols.

Subject Sex

When divided by subject sex, 33 of the 50 correlations were based on male subjects, and 17 of the 50 correlations were for female subjects. The ANOVA-like comparison analysis is presented in Table 11.

As for the previous two study feature groups, the $\underline{H}_B$ value for this study feature was significant; the class of

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Table 11

Analysis of Variation in Correlations Between RPE and HR for Sex of Subject

Source of Variation	K	df	Homogeneity Test	Average Correlation
Total	50	49	H_T = 171.41*	0.68
Between Subject Sex	2	1	H_B = 19.46*	--
Within Subject Sex	--	48	H_W = 151.81*	--
Male	33	32	H = 105.20*	0.71
Female	17	16	H = 46.61*	0.59

*$p < .05$.

correlations using male subjects was significantly different from the class of correlations using female subjects. The $\underline{H}_W$ was also significant, indicating that the correlations within both categories were heterogeneous. The differences among the studies using male subjects were subject mean ages, mode of exercise, type of protocol, and subject fitness level. The differences among the studies using female subjects were the same. Any one or any combination of the study features could modify the relationship of RPE and HR when subject sex was held constant.

Subject Fitness Level

When the 50 correlations were divided by subject fitness level, 24 correlations had been calculated for "healthy but nonactive" subjects, four correlations were for "active" subjects, one correlation was for "mixed" subjects, one correlation was for "sedentary" subjects, and the remaining 22 correlations were for subjects categorized by their $\dot{V}O_2max$. $\underline{H}$ values were calculated for the "healthy-nonactive" class, and the "active" class. However, the correlations generated using subjects selected by their $\dot{V}O_2max$ levels could not be categorized into distinct categories because the range of $\dot{V}O_2max$ was too varied across subject sex and age. Therefore, the $\underline{H}_T$ value to measure homogeneity among the correlations for RPE and HR was recalculated to include only those correlations whose subjects were categorized as "sedentary," "healthy but nonactive," "active," and "mixed." Table 12 presents the ANOVA-like comparison analysis.

Results for this study feature grouping indicated that correlations representing the RPE-HR relationship were different when divided by type of fitness level. However, within the categories analyzed, the correlations again remained heterogeneous. H values for the "healthy-nonactive" class and the "active" class were both significant indicating features within the designated studies continued to influence variability among the correlations. The Jackson et al. (1981) study, identified as an outlier earlier in the discussion, was included in the "active" class. Both the type of exercise and type of exercise protocol were mentioned as unusual study features that could influence the variability among the correlations within that class.

Another factor to consider as influential, other than additional features of outlier studies, is the subjective categorization of subjects' fitness levels. The studies within the "healthy nonactive" class had subjects that were simply described as in healthy condition (Arstila et al., 1974; Gamberale, 1972; Higgs & Robertson, 1981;

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Table 12

Analysis of Variation in Correlations Between RPE and HR for Fitness Level of Subjects.

Source of Variation	K	df	Homogeneity Test	Average Correlation
Total	30	29	H_T = 114.52*	.71
Between Subject Fitness Level	2	1	H_B = 74.36*	--
Within Subject Level			H_W = 96.69*	--
Sedentary	1	0	H = 0.00	.41
Healthy Nonactive	24	23	H = 56.21*	.71
Active	4	3	H = 40.84*	.70
Mixed	1	0	H = 0.00	.83

*$p < .05$.

Lollgen et al., 1977; Pederson & Welch, 1977). There were no explanations provided or specific physiological measures mentioned in these studies to indicate how the authors arrived at this fitness level distinction. Borg (1973) and Gamberale and Holmer (1977) categorized their subjects into fitness levels by using their professions (military conscripts, and firemen, respectively). The entire variable of subject fitness level appears vague. The studies using max$\dot{V}O_2$ as indictors of fitness level cannot be categorized because subject sex and age, and the subjective categorizations of the remaining studies appeared too arbitrary. Subsequently, the correlations grouped in the categories that were analyzed could remain different because a method of measuring subject fitness level has not been identified and used universally.

The ANOVA-like comparisons calculated for the five study-feature groups (type of RPE scale, mode of exercise, type of exercise protocol, subject gender, and subject fitness level) revealed that all features except type of RPE scale, yielded significant results between study feature categories. For all five study feature groupings, the categories within each grouping were also significant. These two results together indicated that not only were the correlations different when grouped according to a specific study feature, but they remained varied within the categories. This means that one study feature was not identified as a single factor that could explain the variability among the correlations in the RPE-HR relationship.

The next step was to consider whether two study features could explain the variability among the correlations. The following study feature pairs were considered: (a) exercise mode and gender, and (b) exercise mode and exercise protocol.

Then the 50 correlations were divided by exercise mode and gender, 31 correlations came from studies on males on the bicycle ergometer, 9 correlations were from studies on females on the bicycle ergometer, one correlation was from a study on males on the treadmill, 8 correlations were from studies on females on the treadmill, and one correlation was from a study on males in the 1.5 mile run. Table 13 presents the H values for these categories.

The correlations for males on the bicycle ergometer and females on the treadmill remained heterogeneous. However, the H values for correlation for females on the bicycle ergometer were homogeneous. For the heterogeneous groups other study features continued to modify the relationship. For females on the bicycle ergometer the average correlation represents the relationship between RPE and HR.

Table 13

Homogeneity Values for Exercise Mode and Gender

Category Groupings	K	df	Homogeneity Value	Average Correlation
Males--Bicycle Ergometer	31	30	65.23*	.73
Females--Bicycle Ergometer	9	8	3.82	.83
Males--Treadmill	1	0	--	.43
Females--Treadmill	8	7	27.27*	.57
Males -1.5 mile run	1	0	--	.16

$p < .05$.

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Table 14 presents the H values and number of correlations per group when the 50 correlations are divided by exercise type and exercise protocol.

Correlations for the bicycle ergometer with a progressive continuous protocol, the treadmill with a progressive continuous protocol, and the treadmill with a one-level submaximal protocol all remain heterogeneous. Other study features continue to modify the relationship between RPE and HR. The correlations for the bicycle ergometer with a one-level maximal protocol and the bicycle ergometer with a progressive intermittent protocol are homogenous; the average correlation is representative of these study feature groupings.

In both of the double study feature groupings, cells remained heterogeneous. This indicated that study features other than the two indicated continue to modify the RPE-HR relationship. This is interesting considering some of the cells had a small number of correlations. The cells that were homogeneous indicated that the two study features considered were the modifying agents if the H_W for each study feature group was heterogeneous when considered alone.

The remaining possibilities for double or triple study feature groupings yielded cell groups too small to calculate H values. Therefore, studies in these

Table 14

Homogeneity Values for Exercise Mode and Exercise Protocol

Category Groupings	K	df	Homogeneity Value	Average Correlation
Bicycle Ergometer--Progressive Cont.	29	28	57.32*	.74
Bicycle Ergometer--One-Level Max	2	1	0.27	.59
Treadmill Progressive Cont.	7	6	26.31*	.57
Bicycle Ergometer Progressive Inter	7	6	2.25	.86
Treadmill--One-Level Max	2	1	26.66*	.09
1.5 Mile Run One-Level Max	1	0	--	.16
Bicycle Ergometer--Random Inter	1	0	--	.63
Treadmill--One Level Submax	1	0	--	.43

heterogeneous groupings must be examined qualitatively to identify unusual study designs or other unusual study features that may be influencing the relationship between RPE and HR.

CHAPTER V

GENERAL DISCUSSION AND SUMMARY

General Discussion

The purpose of this meta-analysis was to determine whether various study features had a modifying effect on the RPE-PM relationships during exercise. For the RPE-V_E relationship, the RPE-RR relationship, RPE-$\dot{V}O_2$ relationship, and the RPE-blood lactate relationship, results showed that various study features were not needed to account for the diversity among the correlations. The overall tests of homogeneity for all four groupings were not significant. This indicated that studies of these four relationships yielded homogeneous results.

In the RPE-V_E relationship, the homogeneous results seem sensible in light of the fact that the studies considered for the analysis had similar study designs. The subjects were male, their fitness levels were determined by $\dot{V}O_2$max, they exercised on the bicycle ergometer, and their RPE was measured by the 15-point scale. In addition, the average ages of the subjects ranged from 21 to 31 years. In the three other relationships (between RPE and RR, $\dot{V}O_2$, and blood lactate), the study designs were also similar to each other in terms of fitness levels being determined by $\dot{V}O_2max$, similar exercise modality, and RPE being measured on the 15-point scale.

These four relationships did not vary according to subject age and sex, method of measuring subject fitness level, exercise mode, and type of RPE scale. The age ranges studied represented a specific group of individuals. All subjects were categorized into fitness levels according to an objective physiological measure and all subjects were asked to rate RPE using the 15-point scale. Therefore, it is possible that subjects were reporting similar RPE as a function of age, fitness level categorization, and RPE scale type.

For the RPE-HR relationship, the overall test of homogeneity was significant. This indicated the studies of this relationship did not yield homogeneous results. The results, therefore, suggested that various study features were modifying the correlational relationship between RPE and HR. Upon examination of Table 6, there was considerable variability in study designs. Of the 19 studies used in the meta-analysis, 13 studies used male subjects and 6 studies used female subjects. When categorized by fitness level, 12 studies used subjective category designations and seven studies used $\dot{V}O_2max$. Within the latter form of measurement, the range was from 27 ml/kg/min to 74 ml/kg/min. The age range of the subjects was from 8 to 59 years. Fourteen of the studies had subjects exercise on the bicycle ergometer, four studies had subjects exercise on the treadmill, and one study had subjects run on a track. All five exercise protocols were used with different exercise modes. The 15-point scale was used in 16 studies, the 21-point scale was used in two studies, and the 9-point scale was used in one study.

These findings suggested that the combination of study features were somehow modifying the correlational relationship between RPE and HR. Of the two study feature pairs that were analyzed exercise mode-gender and exercise mode-exercise protocol, both had category groupings that were still heterogeneous. In the exercise mode-gender grouping, studies using males on a bicycle ergometer, and studies using females on a treadmill had heterogeneous correlations. In the exercise mode-exercise protocol grouping, studies using the bicycle ergometer with a progressive continuous protocol, studies using the treadmill with a progressive continuous protocol, and studies using the treadmill with a one-level submaximal protocol had heterogeneous correlations.

Studies using males on a bicycle ergometer and those using a bicycle ergometer with a progressive continuous protocol had many more correlations than those studies in the other category-groupings. In that many correlations there could still be considerable variability in the types of design features used. For instance, of the 14 studies that used males on the bicycle ergometer, seven studies used males who were healthy, but nonactive; six studies used highly fit males with $\dot{V}O_2max$ readings that ranged from 43 ml/kg/min to 59 ml/kg/min; and two studies did not provide fitness or activity levels. The ages of these male subjects ranged from 8 to 59 years of age. All five of the exercise protocols were also used.

In the 11 studies that used a bicycle ergometer with a progressive continuous protocol, nine studies used males and two studies used females. The ages of the subjects again ranged from 8 to 59 years. In the fitness-activity level category, six studies used subjects who were healthy but nonactive, four studies used subjects who were highly fit, and one study used subjects with mixed levels of fitness/activity levels.

For the category-groupings that remained heterogeneous but had few correlations within each group (females on the treadmill, treadmill with a progressive-

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continuous protocol, and treadmill with one-level submaximal protocol), also had differences among study features. There were three studies that tested females on a treadmill. Two studies used active subjects, but one study used max$\dot{V}O_2$ to measure fitness level and one study used the subjective "active" category. Two studies tested subjects on the treadmill using a progressive-continuous protocol. One study used subjects with max$\dot{V}O_2$ readings of 51 ml/kg/min and the other study used sedentary subjects. Two studies tested subjects on the treadmill using one-level submaximal protocol. One study used males and one study used females. The study with male subjects used elite athletes with max$\dot{V}O_2$ readings of 74 ml/kg/min. The study with females used subjects who were active on a recreational basis. Therefore, even within category-groupings that remained heterogeneous, differing variables remained that modified homogeneity.

Another variable that should be considered in explaining the heterogeneity in the RPE-HR relationship is subject fitness vs. activity level. Unlike the four homogeneous RPE-PM relationship studies, the RPE-HR studies used activity levels to designate subjects' fitness levels. The categories "sedentary," "healthy but nonactive," "active," and "highly fit," however, are vague, and researchers did not specify how they placed their subjects into these categories. Therefore, subjects placed in the same activity grouping could have very different physiological fitness levels. Attempting to look at whether subject fitness was a modifying agent for the RPE-HR relationship was difficult considering the different methods used to classify subjects into fitness levels.

To compare studies by exercise mode, subject fitness levels must also be similar. A subject with a low fitness level will perceive a particular exercise differently at a given load than a subject with a high fitness level. As mentioned earlier, not only was there a variance in subject fitness level across the studies used in this analysis, but also the methods of categorization were different.

A second point concerning subject fitness that has not been addressed in the perceived exertion literature thus far is training specificity. The concern should be not only how fit a subject is, but what mode of exercise they used to get fit. For example, two female subjects, both with VO_2max with 51 ml/kg/min, might be tested for RPE on the same bicycle ergometer protocol test, one subject being a cyclist and the other subject a runner. According to the training specificity theory, the cyclist's musculature would be better prepared to take the bicycle ergometer test than the runner. Therefore, these two subjects might not report the same RPE at a given bicycle ergometer workload. This is an interesting consideration which should be addressed in a study as a function of subject fitness level.

The problem that arose in analysis of the RPE-HR relationships in this review was that researchers investigating this correlational relationship used very different study designs. How can their results be compared to each other when it has not been determined whether changing just one of the many study features alters the RPE-HR relationship? In this study, it was impossible to determine whether one study feature modified the RPE-HR relationship because other study features remained different and confounded the relationship. Furthermore, with 23 different study feature categories to be analyzed using only 50 correlations, there were too few correlations to test each study feature class. More correlational studies using consistent designs between RPE and HR are needed before all these study features can be examined.

Another point of interest is the overwhelming number of studies that investigated the RPE-HR relationship as opposed to other physiological measures. Fifteen of the total 23 studies tested only the RPE-HR relationship.

The remaining eight studies looked at $\dot{V}O_2$, V_E, RR, blood lactate, or a combination of these measures and RPE. HR is the easiest physiological cue to measure; it requires the least amount of equipment and the least amount of skill to determine. In addition, Borg (1970) developed the 15-point scale on the basis of high correlations between RPE and HR. However, he designed the 15-point scale to test the correlational relationship between perceptual ratings and many physiological cues other than HR. More research is needed to investigate the correlational relationship between HR and other physiological cues, such as V_E, RR, $\dot{V}O_2$ and blood lactate to see if they correlate as well as HR under consistent study designs.

The number of total studies included in this meta-analysis was small. Only 23 of a possible 79 studies initially identified could be used. Researchers need to provide descriptive statistics and elaborate on the specific methods used to identify study features. This review was able to determine that correlational comparisons between RPE and HR were modified by a variety of study features and two study-feature combinations. If future researchers provide the necessary statistical information, objectively measure study features, and hold other study features constant where possible, meta-analyses can be conducted to determine many other specific combinations of study features that may modify the relationship between RPE and HR.

Summary

The purpose of this study was to determine whether various study features affect the strength of the relationship of RPE to specific physiological responses to exercise. Using meta-analysis procedures based on the technique of Glass (1976) and Hedges and Olkin (1985) to analyze the variations in study findings, the following study questions were posed and answered:

1. What are the overall average weighted correlations between RPE and the physiological measures of HR, V_E, RR, $\dot{V}O_2$, and blood lactate?

2. Are the correlations for each relationship homogeneous?

3. Do any of the following features of studies influence the five relationships in Question 1? The study features are:

   a. Type of RPE scale

   b. Mode of exercise

   c. Type of exercise protocol

   d. Subject sex

   e. Subject fitness/activity level

A literature search was conducted using manual and computer methods to identify studies to use in the meta-analysis investigation. From this search, 79 studies were retrieved for initial consideration. Twenty three of these 79 studies yielded the required information needed to conduct a meta-analysis. Correlations from these studies were grouped into five RPE-PM relationships: RPE and HR, RPE and V_E, RPE and RR, RPE and VO_2, and RPE and blood lactate. Overall tests of homogeneity were conducted within each group to determine homoscedasticity and the average weighted correlations.

Results indicated that all RPE-PM relationships, except RPE-HR, were homogeneous. The calculated average weighted correlations were, therefore, representative of the correlational strength between RPE and the specified physiological response to exercise.

For the RPE-HR relationship, the homogeneity test was significant, indicating the study correlations were heterogeneous. The correlations within this group were divided five times by the following study features to determine whether the features influenced the overall heterogeneity of the group: type of RPE scale, mode of exercise, type of exercise protocol, subject sex, and subject activity/fitness levels. Homogeneity tests were conducted for each class within each study feature. These tests, in turn, were used in ANOVA-like comparisons to determine homogeneity between and within each study feature group.

Results indicated that when the RPE-HR correlations were divided by type of RPE scale, the correlations were homogeneous between the study feature categories. Type RPE scale, therefore, appeared not to affect the strength of the relationship between RPE and HR.

For the remaining four study feature groups--mode of exercise, type of exercise protocol, subject sex, and subject activity/fitness level--the homogeneity tests were significant between all study feature categories. These results indicated that when the RPE-HR correlations were divided by one specific study feature class, the correlations were different from the correlations in a second class within that study feature group.

Homogeneity tests were also conducted within each study feature class. Results indicated that within each class within every study feature group heterogeneity existed. This result indicated that not only were the RPE-HR correlations different between study feature categories, they remained different within every class. This implied that when the correlations representing the relationship between RPE and HR were analyzed by one type of study feature, other study features continued to modify their correlational strength.

When the RPE-HR correlations were divided by two study feature groupings, results indicated that some study features were identified as modifiers (females on the bicycle ergometer and bicycle ergometer with a progressive intermittent protocol). However, other groupings remained heterogeneous. Groupings by three study features created cells too small to analyze. These results clearly indicate that further research is needed in the perceived exertion area. Also, for the sake of further meta-analyses, researchers need to report their descriptive data.

APPENDICES

APPENDIX A

KEY WORDS FOR LITERATURE SEARCH

APPENDIX A

LIST OF KEYWORDS

Borg Scale

15-point Scale

Perceived Exertion

Perception of Exertion

Perception of Work

Perceptual Ratings of Exertion (Work)

Perceptual Scale

Rating of Perceived Exertion

APPENDIX B

LIST OF STUDIES NOT INCLUDED IN THIS ANALYSIS

APPENDIX B

LIST OF STUDIES NOT INCLUDED IN THIS ANALYSIS

Albert, I., & Williams, M. K. (1975). Effects of post-hypnotic suggestions on muscular endurance. Perceptual and Motor Skills, 40, 131-139. (Statistics needed were not reported.)

Ariyoshi, M., Tanaka, H., Kanamori, K., Obara, S., Yoshitake, H., Yamaji, K. & Shepard, R. J. (1979). Influence of running pace upon performance: Effects upon oxygen uptake, blood lactate, and rating of perceived exertion. Canadian Journal of Applied Sport and Science, 4, 210-213. (RPE not compared to physiological measures.)

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Knuttgen, H. G. (1975). Physiological factors in fatigue. In G. Borg (Ed.), Physical work and effort (pp. 13-24). New York: Pergamon Press. (Type of exercise not used in this analysis.)

Komi, P. V., & Karppi, S. -L. (1977). Genetic and environmental variation in perceived exertion and heart rate during bicycle ergometer work. In G. Borg (Ed.), Physical work and effort (pp. 91-99). New York: Pergamon Press. (Statistics needed were not reported.)

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APPENDIX C

RAW DATA

Comparison Category RPE and HR

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0010701071008   210165016511018003000300                            2    21  176
0011891101211   210165016511018003000300                            2    21  179
0012491131414   110165016511018003000300                            2    21  179
0010811161717   110165016511018003000300                            2    21  188
0010501182120   110165016511018003000300                            2    21  170
0012111222524   110165016511018003000300                            2    21  175
0011691263028   110165016511018003000300                            2    21  168
0011841313533   110165016511018003000300                            2    21  161
0010861364641   110165016511018003000300                            2    21  167
0010281506859   110165016511018003000300                            2    21  160
002127213181651 103000285210300            05005000000025           2    22  146
002127213181651 106000465210480            06001002502525           2    22  146
002127213181651 109000645210660            06000005002525           2    22  163
002127213181651 112000825210840            06000007502525           2    22  174
002106213181651 115001005211020            06000010002525           2    22  162
002043213181651 118001985211200            06000012502525           2    22  125
0040121203527   110120012011012003000000                            2    22  153
0040121203527   110240024011024006000000                            2    22  157
0040121203527   110360036011036009000000                            2    22  172
0040121203527   110660066011066012000000                            2    22  147
0050101294739   11        11            6000                    04  2    22  183
0050151294739   11        11            6000                    05  2    22  187
0050091294739   11        11            6000                    08  2    22  188
00706911819     110120012014036014000000                            2    21  162
00706311819     120120012014036014000000                            2    21  156
00704311819     110120012011036006000300                            2    21  172
00704611819     120120012011036006000300                            2    21  160
0080671    21   21        34                              1 7   2 412    21  116
009006219472643 30240006015030002750223500                          2    21  187
01002611724     410240024011024000750300                            2    21  183
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011012219312437	103000300120360030001505000			2	21	190
011008237484431	103000300120360030001505000			2	21	188
011013251645627	103000300123360030001505000			2	21	182
011010219312441	103000300120360030001505000			2	11	187
011008237484435	103000300120360030001505000			2	11	188
011012251645629	103000300123360030001505000			2	11	180
0120041233529	1100600060130060030003004020		22	2	21	163
01401221923	2201500150250180			295	21	175
015009220302647	101500170110180030003005500			2	21	264
015011219262133	101500170110180030003005500			2	21	265
0170061222926	1101800240110240045800007500		20	2	22	112
0170061222926	1103600480110480091700007500		20	2	22	103
0170051222926	1105400720110720137600007500		20	2	22	137
0180101273732	110300030011090003060306			2	21	144
0190362182119	0100600060210180	045000000030		2	21	141

Comparison Category RPE and V_E

025006124393144	103600360110360030003005000			2	21	190
026010118262159	10585058511060006840150		24	2	21	177
027006118222159	103000300151800	6000	24	259	22	156
027006118222159	109000900151800	6000	24	259	22	175
027006118222159	103000300151800	6000	49	248	22	156
027006118222159	109000900151800	6000	49	248	22	168
028010118262158	101500300150900	6000		2	21	178
0290031243128	106370637110420063700006000		20	2	21	194
0290031243128	106370637120420063700006000		20	2	21	190
030027118312574	10660084025	120000000000		1	21	152

Comparison Category RPE and RR

031010118262159	10585058511060006840150			24	2	21	147
032006118222159	118001800151800	6000		24	259	21	165
032006118222159	118001800151800	6000		49	248	21	148
033010118262158	101500300151800	6000			2	21	160
0340031243128	106370637110420063370006000			20	2	21	167

Comparison Category RPE and VO2

035006124393144	103600360110360030003005000				2	21	187
036010118262159	10585058511060006840150		24		2	21	152
0370031243128	106370637110420063700006000			20	2	21	197
0370031243128	106370637120420063700006000			20	2	21	192

Comparison Category RPE and Blood Lactate

0200121 2049	103600360250600				165	21	164
021019120513042	102900420150300	6000		22	1	21	115
022012219312437	103000420120360030001505000				1	21	189
022008237484431	103000420120360030001505000				1	21	172
022013251645627	103000420120360030001505000				1	21	175
022010219312441	103000420120360030001505000				1	11	162
022008237484435	103000420120360030001505000				1	11	171
022012251645629	103000420120360030001505000				1	11	174
0230031243128	106370637110420063700006000			20	1	21	177
0230031243128	106370637120420063700006000			20	1	21	163
024027118312574	10660084025		120000000000		1	21	161

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