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THE RELATIONSHIPS BETWEEN PERCEIVED EXERTION, FITNESS AND SELECTED PHYSIOLOGICAL PARAMETERS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled THE RELATIONSHIPS BETWEEN PERCEIVED EXERTION, FITNESS AND SELECTED PHYSIOLOGICAL PARAMETERS submitted by JEREMY M.C. ROSE in partial fulfilment of the requirements for the degree of MASTER OF ARTS.

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Date July 2/86

DEDICATION

This is dedicated to my father,

A.M.T. ROSE, M.A., M.C., LL.B.

Who paid for most of my education. Thanks Dad!

ABSTRACT

This study investigated the effects of fitness and selected physiological variables on perceived exertion. A training group (n=12) participated in a progressive jogging program for six months, while a non-training group (n=8) remained basically inactive. Perceived exertion and physiological measures were taken during two separate treadmill tests which were three months apart. The tests occurred during the second half of the training program.

The results showed that on both tests the training group possessed significantly higher aerobic power and perceived the treadmill test as requiring less effort than the controls. Further analysis revealed that VE $l.min.^{-1}$ and VE/VO_2 were consistently highly correlated with RPE in the training subjects. The relationships between RPE and physiological data were weaker in the control group. The training group also appeared to be more consistent in rating their perceived exertion when compared to controls.

The data was discussed in the light of past research findings. It was concluded that the reliability of the Borg scale might be enhanced by exercise experience or increased association with bodily cues. Decreased RPE's after training might also be a result of increased pain tolerance or fitness gains. Various physiological processes might provide input to RPE; however, minute ventilation or the ventilatory equivalent for oxygen might provide consciously monitored cues which may mediate the input from other sources. The selected nature of the groups and the initial differences found between them might have affected the generalisability of the findings.

Although it was concluded that the Borg scale was a reliable measure of RPE, it was recognised that perceived exertion represents a very complex intergration of psychological and physiological factors.

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1. STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

Perceived exertion has been defined as the subjective rating of the physical work being performed, (Morgan, 1973) and has been investigated with increasing frequency in the last ten years (Pandolf, 1983). Perceived exertion may be an important variable in limiting physical performance, since what an athlete thinks he or she is doing may be more important than what they actually are doing (Morgan, 1981). Morgan (1981) also postulated that the perception of 'pace' (or rate of work) is a cognitive process which is dependant on the accurate monitoring of physical cues. Thus, successful performance may therefore rely upon the ability to perceive physiological feedback from the body (Morgan, 1981). Noble (1982) has presented evidence that perceived exertion has many potential applications in the clinical field, such as pace perception in sports, perceptual recovery from exercise or even the analysis of optimal lifting techniques in industrial settings.

The scientific study of ratings of perceived exertion (RPE) has mainly focussed on the identification of a primary physiological cue which may act as a key input for the effort sense, (Mihevic, 1981). However, other related areas of research have investigated theoretical questions of the relationship of RPE to psychophysics, the effect of different exercise variables (such as exercise modality and duration) on RPE or the clinical or industrial uses of RPE (Pandolf, 1983). More recently interest in the effects of selected psychological states and traits (Morgan, 1981), socialisation (Rejeski, 1981), perceptual style (Robertson, Gillespie, Hiatt and Rose, 1977; Robertson, Gillespie, Mcarthy and Rose, 1978) and hypnosis (Morgan, 1973; Morgan, Hirta, Weitz and Balke, 1976) on RPE has lead to a more interdisciplinary approach to the area.

Measurement of RPE has been attempted by various methods (explained in more detail in Chapter 2); however, one method that has achieved wide acceptance is Borg's 15-point category scale (Borg, 1970). This scale has been used to assess perceived exertion as an overall 'gestalt' which involves the integration of separate cues into a global configuration

(Borg, 1982). A further level of investigation has attempted to ascertain the nature of the input of discrete sensory signals emanating from different regions of the body (Differentiated RPE) (Pandolf, 1978, 1982, 1983). For example, the literature seems to support the concept of separate 'local' (working muscle) and 'central' (cardio-pulmonary) cues to the effort sense (Ekblom and Goldbarg, 1971). Robertson (1982) has suggested that the perceptual potency of these signals is a function of both exercise intensity and task duration.

Although Borg's gestalt of overall RPE represents the integration of many psychological and physiological variables, this complex perceptual process is still not well understood:

> Little of the work which has attempted to delineate the key input to the effort sense has addressed whether or not, or in what manner these physiological responses are monitored and integrated by the individual to determine the perception of effort. (Mihevic, 1981), p.150.

One paradigm that has been used to investigate RPE and it's relationships to various physiological variables has been by training subjects and assessing any concomitant changes in RPE and any independant physiological variables (Mihevic, 1981; Pandolf, 1983). However, few studies have been conducted using this method and even less using female subjects (Skrinar, Ingram and Pandolf, 1983). Training provides a means of altering the work capacity of an individual. Thus for a given absolute submaximal workload, the RPE for the work should be lower for trained (fit) subjects when compared to their untrained counterparts, since the exercise should represent a lesser relative physiological strain for the fitter subjects (Mihevic, 1981). The training literature will be reviewed in more detail in the next chapter; however, there do seem to be some controversial findings. Many authors have found concomitant decreases in RPE and heart rates (an indicator of relative strain) during submaximal work after training (e.g., Docktor and Sharkey, 1971; Knuttgen, Nordesjo, Ollander and Saltin, 1973). However, Patton, Morgan and Vogel (1977) found no difference in RPE at similar levels of work between trained and untrained soldiers even though they were working at different levels of their maximal capacity. These authors suggest that RPE may not be able to distinguish between groups differing in fitness on a cross-sectional basis, but may be affected longitudinally by training.

Ekblom and Goldbarg (1971) found reductions in RPE due to training when work was assessed in absolute terms, although this difference was negated when the work was expressed relative to the individual's maximal capacity. Therefore these authors suggested that RPE is related to the relative cost of physical work. (i.e., $\%VO_2Max.$).

Mihevic, Byrnes and Horvath (1982) have suggested that when using a differentiated RPE model, central RPE is related to the absolute cost of work, but local RPE is related to the relative demands of work. In an investigation on the effects of training on differentiated RPE, Skrinar et al. (1983) found that central and overall RPE (a mean of central and local factors weighted to the most salient factor) decreased even when assessed in terms of relative aerobic demands ($\%VO_2Max.$); however, local RPE increased with training. The results of this investigation suggested that the separate components of differentiated RPE may be affected differently by training.

A further controversy involves the effectiveness of the Borg 15-point scale to differentiate between groups differing in fitness. Mihevic (1979) found differences in RPE between groups of fit and unfit women with a magnitude estimation technique; however, these differences disappeared when RPE was measured by the Borg scale. Similarily Patton et al. (1977) found no differences in RPE between groups differing in fitness on a cross-sectional test. However, the Borg scale does seem to be able to guage the longitudinal effects of training on RPE (e.g., Docktor and Sharkey, 1971; Patton et al., 1977; Skrinar, Ingram, and Pandolf, 1983).

1.2 PURPOSES OF THE STUDY

This study attempted to investigate the relationship of training and RPE further. Specific objectives of the study were:

1. To investigate the relationships of differentiated perceived exertion to selected physiological measures. Perceived exertion was divided into central (CRPE), local

(LRPE), and ORPE (overall) components since these measures may more accurately reflect discrete physiological symptoms (Pandolf, 1983). The selected physiological measures included ventilatory volume ($\dot{V}E$), absolute aerobic power ($\dot{V}O_2$ l.min.$^{-1}$, $\dot{V}O_2$ ml.kg.min.$^{-1}$), relative aerobic power (%$\dot{V}O_2$ Max.), ventilatory equivalent for oxygen ($\dot{V}E/\dot{V}O_2$) and volume of expired carbon dioxide ($\dot{V}CO_2$).

The analysis included an exploratory attempt to calculate a regression equation for overall RPE using selected physiological data as the independant variables. This analysis assessed which factors were the best predictors of RPE in the present study. It was hoped that the analysis might clarify some of the findings in the literature which have attempted to assess the primary sensory inputs to RPE.

2. To investigate the relationship of RPE and training. This analysis employed a training program to improve or maintain aerobic power and capacity in a given group. An inactive group was used to compare any longitudinal effects of training. The two groups were compared on two given absolute workloads.
3. A third objective of the study will be to assess the test-retest reliability of the RPE scale, using a standard work test. The validity of the scale may also be ascertained since a less fit group should find a given absolute workload relatively more stressful than a fit group. The relative physical difficulty of the task should therefore be reflected perceptually.

1.3 NATURE OF THE STUDY

1.3.1 LIMITATIONS

Due to the nature of the training procedure used in this study, one limitation may be the training subject's ability to adhere to the program. The subjects were allowed to train on their own for the majority of the study, thus the volume, intensity and frequency of training may have varied. Although no expensive heart rate monitoring equipment was used the training subjects were taught how to monitor carotid or radial pulses (Fox and Matthews, 1981), therefore the subjects should have been able to use heart rates to maintain the required exercise intensity on their own.

Motivation for training was also offered in the form of financial incentives; a sport's store discount and a financial contract ($50.00 deposit, returnable upon successful completion of the study). The training subjects were instructed to keep accurate records of the weekly training volume (miles/week). It was hoped that all these measures would help the subjects to adhere to the required training levels.

The method of training used in this study represented a certain level of ecological validity since individuals commonly follow exercise programs on their own. The physiological measures also gave an objective measure of the changes achieved by the training program.

Since female subjects aged 18-30 years were used a further confounding variable may be the effect of menstruation on the ratings of perceived effort. Since the treadmill tests were scheduled at precise times in the training program, the day of each subject's menstrual cycle was not taken into account. The evidence on the effect of menstruation on performance and perceived exertion is equivocal at present (Higgs and Robertson, 1981; Stephenson, Kolka and Wilkerson, 1982; Carton and Rhodes, 1985), therefore the extent to which it may confound results is unknown.

It has also been suggested that the time of the day at which the test was conducted may also affect RPE; however, the literature on this topic is both sparse and equivocal (Carton and Rhodes, 1985; Myles, 1985). Although an attempt was made to keep the time of day of the two tests constant for each subject, scheduling difficulties made this almost impossible.

Finally, the different levels of fitness between the two groups at the time of the perceptual tests may also have lessened the strength of any conclusions made about the longitudinal effect of training on RPE. Although the training and non-training groups appeared to have similar levels of fitness ($VO_2Max.$) at the pre-test stage of the study, problems in the treadmill protocol necessitated a change in test protocol for the mid and post-tests (see section 3.5.2). Thus valid comparisons could only be made between the mid and post-tests. The level of fitness was therefore substantially different between the two groups at the first perceptual test (mid-test), and any inferences on the effect of training may be weakened. It should also be noted that the two groups were not randomly assigned from the same population, but were selected samples. This may have an effect on the generalisability on the findings.

Although several limitations have been specified, the samples and methods used allowed a comparison of RPE between groups differing in fitness and exercise history, which is similar to the methodology used by Patton et al. (1977). The experimental design also allowed an investigation of the test-retest reliability of the Borg scale in two different groups. The levels of association between RPE and selected physiological variables were also investigated and compared between training and non-training groups.

1.3.2 DELIMITATIONS

This study was delimited to female subjects between the ages of 18-30 years. The subjects were selected from a university population living in Edmonton, Alberta, Canada, thus the results generated from this sample may not be generalisable to other populations. It should also be noted that the training and non-training groups represented self-selected samples from a given population, and were not randomly assigned. It is possible that the groups might have represented two different populations. The nature of the sampling may therefore affect the strength of any conclusions about the effects caused by the training program.

The training modality used was restricted to a weight-bearing aerobic activity (jogging/running), with limited calisthenic exercises for overall body fitness (sit-ups, push-ups).

Finally, the physiological variables measured during the perceptual test were delimited to minute ventilation (VE $l.min.^{-1}$), aerobic power (VO_2, $l.min.^{-1}$ and $ml.kg.min.^{-1}$), expired carbon dioxide (VCO_2 $l.min.^{-1}$), ventilatory equivalent for oxygen (VE/VO_2) and relative aerobic power ($\%VO_2max$) during a treadmill test to exhaustion. No invasive measures were taken. Perceived exertion was measured with the Borg 15-point scale (1970), using the differentiated method developed by Pandolf (1975, 1978, 1982, 1983). This method allows the division of RPE into central (CRPE), local (LRPE) and overall (ORPE) components, a full description of these constructs will be given in the next chapter.

2. A REVIEW OF THE LITERATURE

2.1 PSYCHOPHYSICAL METHODS AND PERCEIVED EXERTION

The perception of exertion has been investigated since the late 1950's, and has been researched as a branch of psychophysics (Borg and Noble, 1974). Psychophysics is an area of psychology which investigates the growth of 'perceptions' relative to a given stimulus intensity. [illegible]-scale level of measurement was developed by [illegible] Stevens (Borg and Noble, 1974). Based on the concepts developed by Stevens, Borg and his colleagues began to investigate the stimulus (S) - response (R) relationships between exercise intensity (S) and perceived exertion (R), during bicycle ergometer work (Borg 1973, Borg and Noble 1974). Initially these researchers used short term exercise bouts (less than 1 min.), and found that a reliable measure of perceived exertion (PE)(defined here as perceived pedal resistance) could be obtained (Borg 1973).

In these experiments Borg and his colleagues found that the perception of 'force', followed a 'positively accelerating function', described by the general equation:

$$R = a + c.S^{1}$$

Where: R = Subjective Force, a = a perceptual noise constant, c = a measure constant, S = stimulus intensity and ^{1} = the exponent.

The perceptual exponent here was found to be 1.6 (Borg, 1973), which was comparable to the exponent found by Steven and Mach (1959, cited in Pandolf 1983), for perceived handgrip force.

Initially Borg and his associates used a technique known as 'halving', in which subjects adjusted their pedalling resistance to a value perceived to be one half of an initial workload. The perceptual exponent was derived from deviations from the actual half value (Borg and Noble, 1974).

Research on longer term work required slightly different techniques, due to the effects of memory error, and adaptation to the exercise stress (Borg and Noble 1974). Borg used a longer period of exercise (4-6 mins. per load) with both ratio and magnitude estimation methods for the perception of effort (Pandolf, 1983). Magnitude estimation involves the subjective assignation of a number to a given work level, numbers are then assigned to subsequent intensities, in terms of their relative magnitude to the initial work level (i.e., if the initial level is 10, work twice as hard would be perceived as 20). Ratio estimation requires the subject to estimate the ratio of percentage magnitude of a given level of exercise, relative to a standard.(i.e., a percentage relative effort scale, in which the perception of force is given as a percentage of maximal effort (Pandolf, 1983)).

Due to the 'steady-state' physiological responses seen in these experiments, Borg suggested that a new formula should be developed which would contain an intensity constant (b). These two constants (a and b) describe a point where the 'perceptual' curve starts to accelerate (Noble, 1973; Pandolf, 1983). The new equation for longer term exercise was rewritten as:

$$R = a + c.(S-b)^{1.6}$$

Where R, c and S are as above. 1.6 = the exponent, a is a basic 'intensity constant' (e.g., 200 Kpm/min.$^{-1}$), b is a basic physiological constant.

Borg and Noble (1974) suggested that when describing the psychophysics of muscular work "a should be positive, b should be 0." It was also suggested that this function describes the growth of lactic acid concentration with increasing workloads on the bicycle ergometer, at intensities greater than 50% VO_2 Max.

Borg (1962), Rejeski (1981), Carton and Rhodes (1985) have all warned about the importance of distinguishing between perceived effort (short term work) and perceived fatigue (long term work). Fatigue and exertion may therefore be perceived as different constructs. Teghtsoonian, Teghtsoonian and Karlsson (1977) when investigating the interaction between fatigue and exertion found that fatigue changed the perceptual exponent of perceived effort. The nature of this interaction was not clear since perceived handgrip force in a fatigued state appeared to be easier with low forces, but harder with higher forces when compared to a non-fatigued condition. A similar trend was found for cycling exercise. These authors speculated that fatigue may affect the sensitivity of effort perception thresholds, which may help to explain any increases in variability in RPE at high intensity workloads (Carton and Rhodes, 1985). There is a need for further clarification of the interaction of fatigue and effort perception.

Borg (1982), however, experienced some difficulties during his earlier experiments such as the differences between the psychophysical techniques used, and the difficulty the subjects had in using them. Borg also found inter-individual comparisons were difficult to make due to the different values assigned to a given level of work by different subjects.

2.1.1 THE DEVELOPMENT OF THE BORG SCALE

In order to overcome the difficulties caused by comparing different techniques and individuals and using complicated methods Borg developed a <u>rating scale</u> in 1962 (Pandolf, 1983). The first attempt produced a 21 point scale, which correlated highly with Heart Rate (r= 0.80 - 0.90), during incremental work. This early scale was a simple and direct estimation of subjective intensity (Borg, 1982).

The scale was changed in 1970, to a 15 point scale (Borg and Noble, 1973; Pandolf, 1983). (See figure 2.1). The new scale (Borg 1970), was constructed to increase the linearity of RPE, Heart Rate (HR), and workload. This is a Lickert-type scale with the terms light, somewhat hard, and hard. The scale is assumed to be linear where the interval between R_4 and R_5 equals that of R_1 and R_2. Borg (1982) also claimed that for middle-aged subjects working on the bicycle or treadmill Heart Rate=RPE X 10.

Contrary to Borg's (1982) assertion that the scale represents an interval level of measurement, Pandolf (1983) suggested that the scale, "is probably an ordinate scale". Other researchers, however, have treated the scale as an interval scale, since procedures such as analysis of variance (which depends on the computation of means (Hopkins and Glass, 1978)) are often used (see for example Noble, Maresh, Allison and Drash, 1979; Smutok, Skrinrar and Pandolf, 1980; Young, Cymerman and Pandolf, 1982).

The precise relationship of HR and RPE has also been questioned (this controversy is discussed in a later section). Borg (1982) recognized this problem since he mentioned that

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

Figure 2.1 The 15 - point Borg Scale. (Borg, 1977)

"The meaning of a certain heart rate value as an indicator of strain depends on age, type of exercise, environment, anxiety, and other factors", (Borg 1982, p.379).

The advantage of such category rating methods seem to arise from the 'absolute' nature of the values obtained (c.f., the relative nature of ratio-scaling techniques) and the ease of use. Inter-individual and between-task comparisons can also be made. The category scale can also be used to study the effects of training (Pandolf 1983). Borg (1982) has suggested that the 15-point scale is best for most simple applied studies.

2.1.2 VALIDITY AND RELIABILITY OF THE BORG SCALE

Borg (1970) reported that his 15-point scale was constructed from the linear relationship of HR and workload; and found high correlations (r = 0.80-0.85) between HR and RPE. Since heart rate can reliably show the actual increase of exercise stress in the individual (Skinner, Hutsler, Bergsteinova and Buskirk, 1973), the correlation of actual work (HR) and perceived work (RPE) should be valid.

The reliability and validity of Borg's (1970) scale has been questioned (Carton and Rhodes, 1985). Noble (1979) noted that RPE values did not parallel recovery heart rates following a maximal treadmill run. This author suggested that the RPE scale did not validly approximate the metabolic processes involved during exercise recovery. Another study conducted by Ulmer, Janz and Lollgen (1977) attempted to assess the differential RPE response to the 'stress' (workload) and the 'strain' (heart rate response) of physiological work. Strain was defined as being the subjective response to the stress. The results from partial correlation analysis revealed that RPE was more related to the workload than to HR. These findings support some of the other literature that the RPE/HR relationship may not be as strong as it was first thought. Although RPE and HR are correlates heart rate itself may not provide a valid mechanism for providing feedback for the perception of physical work.

Skinner, Hutsler Bergsteinova and Buskirk (1973) investigated the reliability and validity of the Borg Scale and suggested that one reason for the high correlations found was the incremental nature of the tests. Subjects may base RPE's on previous workloads and the expectancy of increasing exercise intensity. Subjects were presented with four tests, two on progressively increasing work and two on randomised presentation of the same work loads. Results were then compared across the progressive and randomised tests. Reliability coefficients across each completed workload showed correlation coefficients of r=0.80 (progressive test) and r=0.78 (random test). There were also no significant differences across the randomised and progressive tests. Skinner et al. (1973) concluded that RPE from a progressive test was of a sufficiently high reliability and validity.

Stamford (1976) accepted the above findings, but questioned the reliability and validity of interval RPE ratings (given regularly during a test) and terminal RPE (given at the final minute of work) when taken during exercise involving constant effort, progressive work and workloads presented in a random order. This author postulated that the use of interval ratings may affect terminal ratings (by comparison effects). Subjects were presented with exercise modes (bench stepping, cycling, walk/jog) in a randomized order. Results showed high reliability for all trials r=0.90 for the terminal ratings (bicycle ergometer), and high validity across progressive, oscillating or constant loads. Therefore RPE's did not seem to be influenced by prior ratings (Stamford 1976).

Overall the RPE scale seemed to be supported as a valid and reliable instrument for assessing subjective stress during physical work.

2.1.3 THE NATURE OF RATINGS OF PERCEIVED EXERTION (RPE)

Overall perceived exertion represents an individual's integration of a variety of physiological sensations (Pandolf, 1983). The sensory signals that act as an input for this 'effort sense' emanate from the working muscles and joints, cardiovascular and respiratory functions and from the central nervous system. Edwards, Melcher, Hesser, Wigertz and Ekelund (1972) were unsure whether sensory afferent information that was not consciously perceived could contribute to the sensation of exertion. Noble, Metz, Pandolf and Cafarelli (1973) suggested that although perceptual responses to exercise are based on physiological changes, attention is probably given to the externalisation of these processes (such as increased ventilation) rather than to the processes *per se*. Mihevic (1981) concurred with both of the above arguments, but also presented the psychologist's viewpoint that any perception is a process dissociated from conscious awareness. Mihevic (1981) argued that although the active monitoring of physiological cues allows for the regulation of exercise intensity (the associative strategies found by Morgan and Pollock (1977) for example), the perception of effort may be altered by unconscious processes.

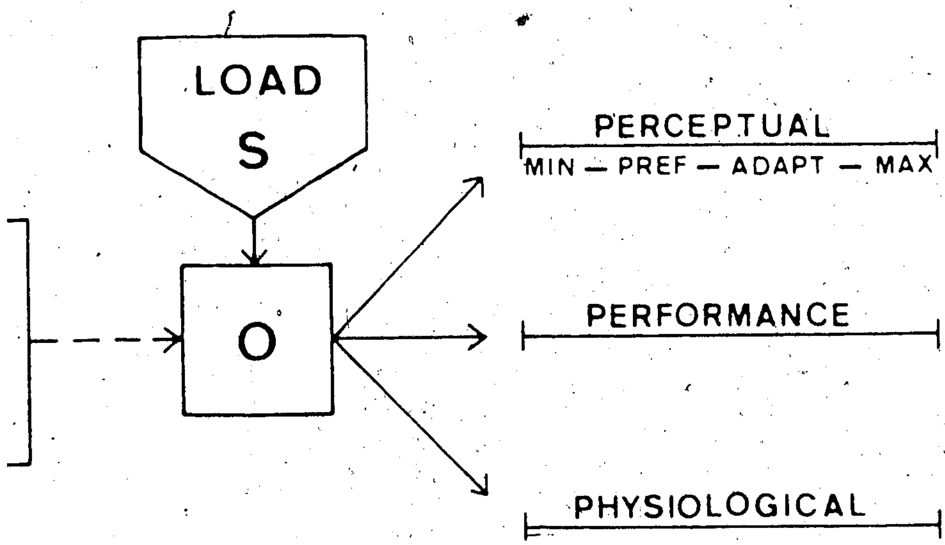
> Thus, while a conscious awareness of certain discrete physiological cues is likely to affect the evaluation of perceived exertion in some manner, the total exercise demand determined by the conscious and/or unconscious integration of multiple physiological responses may well represent the more critical basis for the perception of effort. (Mihevic, 1981, p.150).

Perceptions and experiences are therefore integrated into a configuration or a "Gestalt" of perceived exertion (Borg, 1982); however, the exact manner in which these are monitored or integrated is still not fully understood (Carton and Rhodes, 1985; Mihevic, 1981; Robertson 1982).

The central processing that is thought to be a part of the perception of exertion also seems to be subject to mediation by various psychological states. Certain psychometric variables may interfere or change the cognitive processing of incoming sensory information (Pandolf, 1983). Morgan (1973) has noted that the average correlation of RPE and HR is r=0.82, thus 33 percent of the variance in this relationship remains unaccounted for. Morgan (1973), suggests that a portion of this unexplained variance may be due to psychometric factors (this will be discussed later).

Borg (1970) recognised the complex interactions involved in perceived exertion and attempted to explain the processes involved in terms of the 'Three Effort Continua', (see Figure 2.2). Borg and Noble (1974) explain this continuum in terms of the three levels of stress indicators.

1. Physiological indicators of stress: (objective criteria).
2. Perceptual Data: such as the ratings of perceived exertion which might complement the



e three effort continua, Borg (1970, 1977).

physiological data.

3. The Performance itself: this indicates a maximal effort or a preferred working intensity.

Borg (1970, 1977), suggested that there are different levels of intensity associated with each continuum (i.e., min. or max.), which may represent adaptation or preference levels. Thus for a given zone of subjective intensity in one continuum, there are corresponding levels in the other two. Since there is no linear translation between different levels, each must be studied separately and the data integrated (Borg, 1977). The recognition of the three continua has encouraged a multi-disciplinary approach to the area (Pandolf, 1983), and was seen as a way of studying work thresholds within each continuum and relationships between the continua (Borg, 1970).

2.2 THE CONCEPT OF PHYSIOLOGICAL INPUTS TO THE EFFORT SENSE

2.2.1 CENTRAL AND LOCAL FACTORS

Although Borg (1961, cited in Mihevic, 1981) has recognised the importance of physiological sensory input from the muscles and cardiovascular systems, Ekblom and Goldbarg (1971) have been credited as the first researchers to formally propose 'central' and 'local' sensory inputs to RPE (Pandolf, 1983). Central cues refer to sensations from the cardiopulmonary system, (e.g., tachypnea, heart rate, dyspnea). Local cues were seen to arise from feelings of strain in the working muscles and/or joints (Ekblom and Goldbarg, 1971). The relationship between the two clusters was seen to be very complex and dependent on the size and type of muscle groups used. Ekblom and Goldbarg (1971) suggested that local factors dominate small muscle group use. The input from central cues became more important, and added to the local strain, during work using large muscle groups since this type of work tends to stress the cardiopulmonary system.

The concept of local and central factors has been reviewed in detail by several authors in recent years (see Mihevic, 1981; Pandolf, 1978, 1983; Carton and Rhodes, 1985). The most pertinent physiological cues will be briefly reviewed here. The reader is referred to the reviews cited above for further detail. Mihevic (1981) cautioned readers to be aware of the different meanings of the term 'central' when used within different contexts. The central factors in the RPE literature defined above should not be confused with the 'central' (Central Nervous System) factors referred to in the fatigue literature. At the end of this section a model will be presented which attempts to integrate the inputs of local and central factors in RPE during exercise.

2.2.2 CENTRAL FACTORS

It has already been mentioned that physiological cues may be monitored at both an unconscious and a conscious level. This view was supported by Robertson (1982) and may be important in central factors since some of the proposed cues such as HR or VO_2 may not be consciously monitored. For example, Mihevic (1981) mentioned that no evidence was available to suggest that oxygen consumption can be consciously monitored. Relative aerobic power (%VO_2 Max.) has been suggested as a potent cue for RPE; however, it's salience may be mediated by a more directly perceivable process. Examples of 'consciously' perceived cues are respiratory rate (RR), minute ventilation (VE) and respiratory discomfort. As mentioned previously the literature is unclear as to the possible 'unconscious' monitoring mechanisms.

Pandolf (1983) suggested that more evidence disputed rather than supported the importance of central cues as inputs to the effort sense. Evidence for and against these cues will be briefly discussed.

2.2.2.1 HEART RATE

The linear relationship of HR and RPE was the basis for Borg's 15-point scale (Borg 1970). Robertson (1982), reported correlation coefficients (r) of 0.42 to 0.94 between HR and RPE. He suggested that this relationship is purely correlational in nature; and agreed with Mihevic (1981) that HR during exercise is not consciously perceived. Mihevic (1981) also suggested that since the Borg scale was designed to follow HR during incremental exercise a strong relationship would be expected under normal conditions.

The importance of heart rate as a primary cue for perceived exertion has been tested by various experimental manipulations during exercise by drugs or ambient temperature. Ekblom and Goldbarg (1971) and Davies and Sargeant (1979) investigated the effect of autonomic nervous system blocking agents on HR during exercise. These drugs alter heart rates during exercise at standard power outputs by manipulating sympathetic and parasympathetic input. The results of these two experiments were similar, RPE responses to exercise during the drug treatments were negatively correlated to HR. Thus as HR's were artificially increased or decreased by the drugs, RPE's decreased and increased respectively.

Skinner et al. (1973) used environmental temperature to increase HR at a given workload, and found that the relationship of HR and RPE remained similar in both 24° C and 32° C conditions. In a lean group both HR and RPE increased in the heat, whereas elevated temperature did not cause any change in RPE or HR in an obese group. Pandolf, Cafarelli, Noble and Metz (1972) also used temperature to manipulate HR. The results of Pandolf's study showed no changes in RPE at a given workload regardless of ambient conditions, even though HR's were significantly elevated at the higher temperatures. Similar results were found by Bergh, Danielson, Wennberg and Sjodin (1986) who found that heat stress (45°C) shifted the HR-RPE relationship so that RPE in the heat was lower for a given heart rate when compared to exercise at 15°C.

The literature suggests that HR is not a major perceptual input to central or overall perceived exertion. However it must be remembered that the experimental methodologies used may affect the haemodynamics of the cardiovascular system. Various compensations via blood pressure or stroke volume may occur to maintain cardiac output when HR is experimentally manipulated. Thus cardiovascular signals may be important inputs to RPE, but they may have been inappropriately attributed to HR (Mihevic, 1981; Robertson, 1982). For example blood pressure has recently been suggested as a possible input to RPE (Pandolf, Billings, Drolet, Pimental and Sawka, 1984). Pandolf et al.

(1972) has also suggested that manipulations of HR by ambient temperature may affect nutritive and non-nutritive blood flow. These altered haemodynamic processes might possibly alter the HR-RPE relationship.

2.2.2.2 OXYGEN CONSUMPTION, (VO_2)

Robertson (1982) has shown correlation coefficients between VO_2 and RPE of r=0.76 to 0.97 and suggests that RPE is more related to *relative* VO_2 (percent. VO_2 Max.) than *absolute* values (VO_2 $l.min.^{-1}$). Studies by Ekblom and Goldbarg (1971), Skinner et al. (1973) and Sargeant and Davies (1979) supported this contention. Manipulations of aerobic capacity by red cell reinfusion (in Robertson, 1982), and altitude (Young et al., 1982) have also supported the relationship of RPE and relative VO_2.

Edwards et al. (1972) found evidence to support VO_2 as a potent signal for RPE in both continuous and intermittent work. However the small sample size (n=3) may have affected these results.

In addition to the problem of the method of monitoring VO_2 by an individual during exercise, Mihevic (1981) also warned that relative exercise intensities may not equate with other physiological responses such as hyperpnea or lactic acid production which may change with training. Mihevic (1981) therefore suggested that other more readily monitored responses giving input to RPE, may mediate the cues given by relative VO_2.

Some studies have reported results which argue against the use of VO_2 as a signal to RPE. Pandolf, Kamon and Noble (1978), using eccentric or concentric work found that VO_2 did not seem to be a dominant input to RPE.

Cafarelli (1978) investigated the effects of six minutes cycling at a constant resistance, but with different pedalling rates. Results showed that VO_2 reached a steady state during the first two or three minutes of work, but RPE continued to increase during the exercise. This suggested that VO_2 was not related to perceived exertion when local (strain) signals were held constant.

More recently Pandolf et al. (1984) using differentiated RPE (see later sections) investigated the role of a variety of physiological cues in perceived exertion. In a multiple regression analysis of the results, VO_2 contributed least to the total variance (R^2) in RPE.

It might be concluded that relative VO_2 is a more potent input to RPE than absolute VO_2, even though they both may not be directly sensed. However, the literature is equivocal on this point. The differences found may be due to the different protocols used. Carton and Rhodes (1985) also mentioned that although VO_2 increases linearly with workload, RPE increases in a positively accelerating manner, thus VO_2 is probably indirectly associated with RPE.

2.2.2.3 VENTILATORY INPUTS, MINUTE VENTILATION (VE) AND RESPIRATORY RATE (RR)

Robertson (1982) suggested that breathlessness and hyperpnea can be consciously monitored. This could be an important cue if minute ventilation (VE) became uncomfortable at higher respiratory rates. Cluster analysis of cardiopulmonary symptoms has identified a number of ventilatory signals such as shortness of breath, panting, difficulty in breathing and chest pain (Borg et al., 1976 (cited in Robertson, 1982); Weiser and Stamper, 1977). Weiser and Stamper (1977) found a high correlation ($r=0.94$) between respiratory rate (RR) and an increase in cardiopulmonary distress. These authors concluded that physiological changes in any system (i.e. [illegible]cal) are highly associated with the severity of reported symptoms. It therefo[illegible] f pulmonary data may be a potent source of input to central RPE.

Edwards et al. (1972), also found a significant correlation of RPE and RR with continuous, but not intermittent exercise, and suggested that ventilatory afferent impulses, can be consciously monitored. Such signals may be important with higher workloads.

Noble et al. (1973) found that VE and then RR accounted for the greatest amount of variance in RPE and hypothesized that subjects do not directly sense physiological changes *per se*, but monitor the "externalizations" of the processes that can be directly perceived (i.e., VE, RR or even skin temp.).

Morgan et al. (1976), found hypnotic suggestions of hard work increased RPE with a standard power output. The increase in RPE was also associated with an increase in VE.

Despite evidence supporting ventilatory signals as an input to central RPE, several authors have found contrary findings. Cafarelli and Noble (1976), found little evidence to support VE as an input to RPE when hypercapnia was used to manipulate ventilation; however, it was suggested that the effect of ventilation may become more important at higher exercise intensities (a position supported by Robertson, 1979). Stamford and Noble (1976) also found that VE did not reflect significant RPE differences during bicycle work when different pedalling frequencies were used to elicit a constant power output, (approximately 65% VO_2Max.).

On a methodological note, Mihevic (1981) warned that the hyperventilatory state caused by hypercapnia is different from exercise-induced hyperventilation, thus results should be interpreted cautiously. The effect of VE on RPE would probably increase with higher exercise intensities when the isocapnic buffering of H^+ ions causes hyperventilation. More recently Pardy and Bye (1985), investigated perceived effort in a task designed to fatigue the diaphragm. VE was held constant, but the task was performed under conditions of hyperoxia and normoxia. The results indicated a fluctuation in perceived effort (lungs) when VE was held constant. It was postulated that PaO_2 or the partial pressure of oxygen in the arterial blood flow to the diaphragm may influence the rating of PE (perceived effort). It should be noted that PE was measured on an open ended scale in this experiment.

A mechanism of action of the effect of VE or RR on RPE has been suggested. Bakers and Tenney (1970) found that ventilatory pressure, volume and ventilation could be accurately perceived, with these sensations originating in the chest wall. These authors recognised that the conscious recognition of ventilatory states may be an essential part of a learned response, since athletes seem to 'know' how to breath under certain exercise conditions. Wolkove, Altose, Kelsen, Kondapalli and Cherniack (1981) also found that tidal volume changes can be accurately sensed. Therefore sensory inputs for the perceptions of ventilation may come from the respiratory muscles.

Robertson (1982) suggested that during exercise, the input for control of respiration is taken over by the mechanoreceptors located in the chest wall, lungs and airways (Wolkove et al., 1981). These signals reach their strongest input with peak tidal volume which is achieved at approximately 50% VO_2Max. (Robertson, 1982) and can be directly sensed by the sensorimotor cortex (Wolkove, 1981). Robertson (1982) points out that VE starts to parallel RPE at approximatey 50% VO_2 Max. VE and RR therefore provide a consciously monitored cue, which may be important with the higher exercise intensities (such as near the anaerobic threshold). These cues might be driven either by temporal, chemical or mechanical stimuli. Carton and Rhodes (1985) conclude that the input of a ventilatory signal may be related to the relative exercise intensity being performed, but any theory attempting to explain the perceptual pathway should be considered to be tentative at the moment.

2.2.2.4 VENTILATORY EQUIVALENT, (VE/VO_2)

More recently, evidence has been found to suggest that the ventilatory equivalent for oxygen (VE/VO_2) may be an important signal for RPE. Young, Cymerman and Pandolf. (1982) used chronic and acute altitude exposure to manipulate the physiological response to exercise and found a strong association between these two variables.

Pandolf et al. (1984) found that VE/VO_2 accounted for the greatest amount of variance in RPE during absolute and relative cycle exercise. This represents a new variable to investigate in future research.

2.2.2.5 SUMMARY OF CENTRAL CUES

Several cues have been hypothesized as inputs to central RPE, and evidence has been accumulated that supports and disputes all of them. Differences in scaling methods or research protocols may have caused some of these differences. Among the more likely cues are $\%VO_2Max$. (relative aerobic power), VE and RR (which may be directly sensed), and the ventilatory equivalent for oxygen (VE/VO_2).

2.2.3 LOCAL FACTORS IN RPE

Mihevic (1981), has identified three major inputs to the local effort sense: muscle and blood lactate, golgi tendon activity (GTO) and general muscle sensations.

In contrast to the central factors, Pandolf (1983) suggested that the literature provided more support for local factors in RPE. Weiser and Stamper (1977), concluded that "leg fatigue" symptom scores, could account for 76% of the variability in ride duration for bicycle ergometer exercise. This again supports "local muscular sympoms" as a potentially important input to RPE. The individual factors will be discussed briefly below.

2.2.3.1 MUSCLE AND BLOOD LACTATE

Ekbolm and Goldbarg (1971) supported blood lactate as a cue for RPE since they found that the two were highly correlated. RPE was the same for a given level of blood lactate before and after 8 weeks of training. Edwards et al. (1972) found correlations (r's) of between 0.633 and 0.830 for RPE and lactate under different conditions.

Young et al. (1982) found a similar association of RPE and blood lactate. Blood lactate levels were significantly decreased after 18 days high altitude exposure (14,000 ft), and were associated with a reduction of the salience of local RPE. Carton and Rhodes (1985) have cautioned however that the levels of lactate found after long term high altitude exposure (2mMol./litre) were unusually low for a low fit group (VO_2 Max. = 42.2 ml/kg.min.$^{-1}$ +/- 1.9 ml.) being exercised at $85\%VO_2$ Max. and suggest the results should be interpreted with caution. Carton and Rhodes (1985) also questioned the effect of acclimatisation on absolute and relative workloads at altitude (see Carton and Rhodes, 1985, page 210).

Using a polynomial analysis of the power functions Noble, Borg, Jacobs, Ceci and Kaiser (1983) found a high correspondence between muscle and blood lactate, and

RPE measured on a new ratio 10 point scale. In another experiment using this new category ratio scale (CR-10), Borg et al. (1986) found that a combination of heart rate and blood lactate was a better predictor of RPE than any one variable taken alone. In this investigation blood lactate showed a perceptual exponent of about 3 (see equations in section 2.1). Another recent investigation (Bergh et al., 1986) showed that blood lactate and RPE possessed a similar growth curve. This relationship was unaltered by heat stress (45°C).

Pandolf (1984) also found lactate to contribute highly to the variance in RPE, in both arm cranking and cycling exercise. Robertson, Falkel, Drash, Spungen, Metz, Swank and Le Boeuf (1982) found that local RPE was significantly lower in induced alkalosis conditions ($NaHCO_3$) when compared to placebo conditions ($CaCO_3$). This effect was only present in the higher exercise intensities (80% VO_2Max.) and not at lower levels (40% VO_2Max.). This supports the argument that lactate may only be a potent input to RPE at higher workloads.

Some evidence has been found against lactate as a cue for RPE. Poulus, Doctor and Westra (1974), investigated the effects of infusion of 8% $NaHCO_3$ on RPE. $NaHCO_3$ corrected exercise induced acidemia, but had no effect on 'feelings of fatigue'; however, the danger of equating fatigue with effort has already been mentioned. The author concluded that blood ph was not associated with RPE.

Stanford and Noble (1974), found no relation of RPE and lactate, when the exercise at 65% VO_2 Max. was manipulated by changing pedalling frequencies. A similar protocol used by Lollgen, Graham and Sjogaard (1980) resulted in similar findings. RPE was found to be lower at the higher pedalling frequencies, but lactate accumulation could not account for this.

These ideas should be interpreted in the light of certain other findings. It has already been mentioned by several authors that exercising individuals at similar relative exercise intensities may not equate other physiological responses to exercise (such as lactate production); however, it is generally accepted that blood lactate may only affect

RPE at certain critical exercise intensity thresholds. Therefore individual differences in $\%VO_2$ Max. when reaching aerobic or anaerobic threshold may have influenced research on RPE and lactate.

Evidence seemed to support lactate as a possible input to the effort sense, although it is correlational in nature (Pandolf 1983). A mechanism has also been suggested by Mihevic (1981), Pandolf (1978) and Stamford and Noble (1974) who have all mentioned that sensitive free nerve endings may provide a means to consciously monitor muscular discomfort. Mihevic (1981) cautioned that if blood lactate influences exertional sensations its effect is not mediated by metabolic acidosis (supporting the work of Poulus, Doctor and Westra (1974)). However, since increases in VE are known to result from increases in lactate (to correct for blood acidemia), lactate may be sensed via this pathway. It is also suggested that lactate would become a cue at higher exercise intensities (Mihevic,1981).

Other muscle metabolites may provide cues via free nerve ending sensations (Pandolf, 1977). Cafarelli (1977) also supported this view, especially if tension within the muscle causes decreased local blood flow. Lollgen (1980) however found no evidence of metabolites, blood flow, or substrates as a factor in RPE. Carton and Rhodes (1985) suggested that blood lactate may influence RPE through some presently undefined pathway. The interaction of blood or muscle lactate and RPE is therefore not well understood (Robertson, 1982).

2.2.3.2 GOLGI TENDON AND GENERAL LEG MUSCLE SENSATIONS

Mihevic (1981) and Pandolf (1983), both suggested that the major 'local' symptoms that may provide cues for the effort sense are as follows: mechanoreceptors and proprioreceptive feedback, golgi tendon organ (GTO) activity and general muscle sensations deriving from the muscle, skin, joints and ligaments. One major problem with research into these particular factors is that these cues are difficult or nearly impossible to quantify (Mihevic, 1981; Pandolf 1978, 1982, 1983).

Mihevic (1981) mentioned that much of the original data on leg cues came out of research on the effect of different pedalling rates and power outputs on RPE. Pandolf and Noble (1973), manipulated both power outputs and pedalling frequencies during bicycle ergometer exercise. The results showed increases in RPE at equivalent power outputs, with the lower pedalling frequencies. Since VO_2 was similar at the same power outputs, it was suggested that <u>local strain</u> factors were important inputs to RPE. Similar results were found by Stamford and Noble (1974), using different pedalling rates (40,60 and 80 rpm) to achieve a constant power output (960 kgm/min). These authors found significant differences in RPE as a result of pedalling rate. Pedalling at 60 rpm was perceived to be less stressful than 40 or 80 rpm during both continuous and intermittent work. Other variables that were measured which might have influenced RPE were VE $l.min.^{-1}$, VO_2, heart rate and blood lactate. Interestingly enough RPE, VE, VO_2 and HR were higher during continuous work when compared to intermittent work. However, since all the physiological parameters were similar across the different pedalling frequencies the authors concluded that the differences seen in RPE may be due to some unmeasured local factor. It was suggested that the local fatigue originating in the joints and supporting connective tissue from GTO activity was a potential input to RPE. This fatigue was seen to be influenced by resistance at 40 rpm and pedalling rate at 80 rpm. The findings that RPE's at 60 rpm (continuous) were similar to those at 40 rpm and 80 rpm (intermittent), in spite of the greater metabolic cost of continuous work, strengthened the suggestion that factors other than the metabolic cost of exercise may influence RPE. Cafarelli (1978) again hypothesised efferent signals from muscle spindles and golgi organ activity, when it was found that VO_2 was not a major input to the effort sense (using magnitude estimation). In this experiment pedalling force was kept constant, but pedalling frequency was changed, muscle fatigue was not implicated here.

The 'salience' of local input may also be a function of the time course of exercise. Cafarelli (1977) used the pedalling rate paradigm and found a strong relationship between integrated electomyography (fibre activity/contraction) (IEMG), resistance and sense of effort. However these factors could not account for differences in effort sense at different pedalling rates. Evidence was found to suggest that in the first 15 seconds of exercise input to RPE is entirely local, since pedalling rate was the most important factor here. In this experiment, pedalling frequency was altered so that power output could remain constant, thus at the lower pedalling frequency (30 rpm.) the resistance (local strain) was greater. Cafarelli's (1977) findings are an important part of the various models described later.

Noble, Maresh, Allison and Drash (1979) attested to the effect of local signals on RPE. These authors investigated the perceptual and physiological recovery of participants in the 1976 Boston marathon.. It was found that RPE was higher at a given HR up to a week after the race, and was associated with the local muscular soreness and stiffness resulting from the run.

2.2.3.3 SUMMARY OF LOCAL FACTORS

Several factors, muscle and/or blood lactate, muscle metabolites and proprioceptive activity have been postulated as possible inputs to the local effort sense. Some disputing evidence has been found, but most literature has supported the importance of local cues. The difficulty of measurement associated with some of these factors may have prevented validating research in this area.

2.2.4 RESEARCH INTO DIFFERENTIATED RPE

In support of Ekblom and Goldbarg's (1971) theory of central and local factors, Kinsman, Weiser and Stamper (1973) developed the Physical Activity Questionaire (PAQ) from a key cluster analysis of subjective responses during exercise. This analysis revealed three major symptom clusters: fatigue, motivation and task aversion. Kinsman and Weiser (1973) subsequently reported that the bicycling 'fatigue' cluster of the PAQ, was composed of three sub-groups; general fatigue, leg fatigue and cardio-pulmonary distress. Pandolf (1975, 1977) has developed a model for perceived exertion based on the above data in an attempt to integrate the various levels of subjective symptomatology during physical work (See Figure

2.3).

The model is pyramidal or hierarchical in nature, and at the base level discrete symptoms have their basis in the physiological changes. In an attempt to support this model, Weiser and Stamper (1977) attempted to correlate the increase in subjective symptom reporting by the PAQ with an increase in physiological stress. Their findings indicated significant correlations of EMG amplitude to reported leg fatigue, and respiratory rate to perceived cardiorespiratory distress, (Weiser and Stamper (1977)).

It was therefore concluded that 'construct validity' was present, and undifferentiated RPE could be divided into the RPE of central and local factors. Differentiated RPE should thus reflect specific central and local physiological events (Robertson, 1979). Pandolf's (1982) review supports the concept of differentiated RPE, but calls for more carefully designed studies.

The differentiated model is a basis for RPE research, regardless of the types of measurement scales used. Instructions are given to the subject to report central (cardiopulmonary), local (leg fatigue and strain factors), and overall, (a combined score weighted towards the most salient factor),(See Appendix B for details).

Rejeski (1981), supported Pandolf's (1975) model for providing an integrative framework for research into RPE, but disagreed with the model's implication that psychological dimensions (. task aversion and motivation), have their basis in physiological symptoms.

In most experiments local RPE appears to be dominant, with overall and central factors contributing in that order, (Pandolf 1982). This seems especially true during bicycle ergometer work. So far the only study in which this order has been changed was performed by Young et al. (1982) where chronic altitude exposure lead to a change in the relative importance of local cues, so that central cues became more important. Local cues appeared to be related to changes in blood lactate; however, some potential problems with this study have been mentioned earlier.

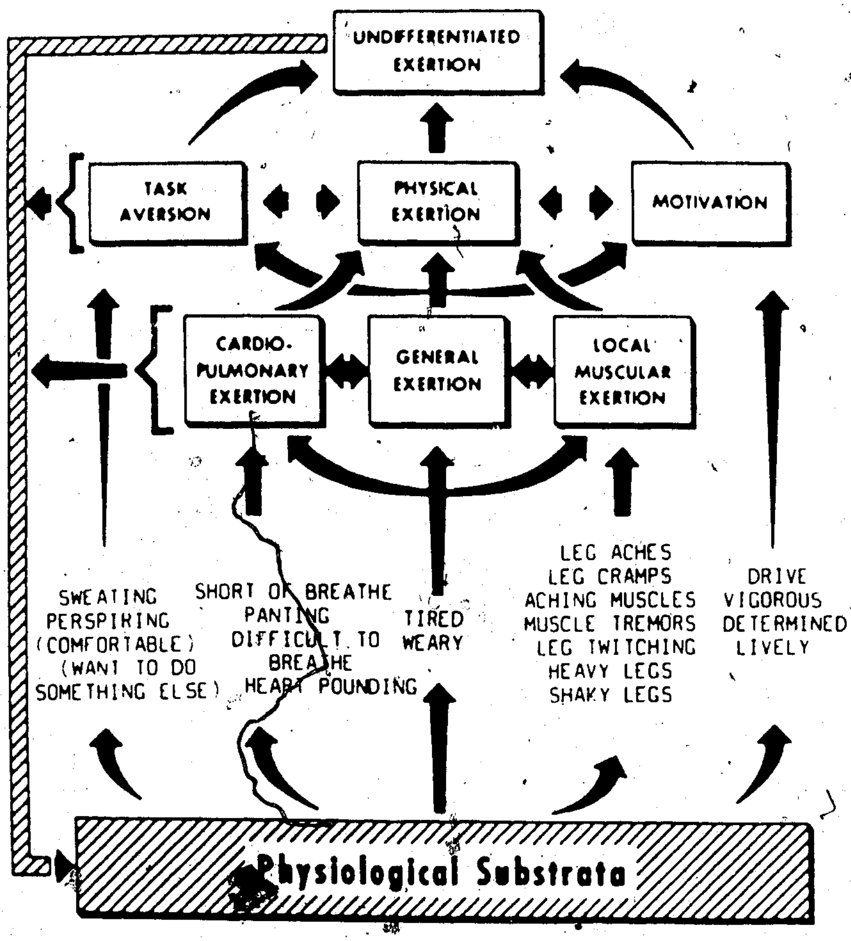


Figure 2.3 A model for Differentiated Perceived Exertion. (Pandolf, 1975, 1977)

2.2.5 INTEGRATION OF LOCAL AND CENTRAL CUES TO RPE

Borg (1982) mentioned that perceived exertion is probably an integration of multiple sensory cues into a 'gestalt' of perception. The relative importance of central and local cues may change according to the salience of that input (Cafarelli, 1977; Young, 1982; Horstman et al., 1979), and since Lollgen (1980) found no evidence for a single central or peripheral cue, it seemed as if RPE must be derived from a number of factors in a complex manner.

Robertson (1982) has developed two models in an attempt to explain the integration of the local and central cues. The first diagram (figure 2.4), presents a model of the relative contribution and time course of central and local signals of exertion.

This model assumes that local factors provide the primary sensory signals, central signals act as an amplifier or gain modifier potentiating local signals in proportion to aerobic metabolic demands. Central factors (such as VE and %VO_2 Max.), begin their potentiating input approximately 30-180 seconds after the initiation of exercise. This corresponds to the time period required for cardiovascular and ventilatory adaptation to exercise (Cafarelli 1977, Robertson 1982).

This model concurs with Horstman, Weiskopf and Robinson (1979), who indicated that local factors are more salient during exercise that does not stress the ventilation or circulation. At exercise intensities where central cues become stressful, the potency of central cues will increase.

Figure 2.5 illustrates the relative contribution of central and local signals at different metabolic intensities. This model utilises three levels of exercise intensity: I, less than 50% VO_2 Max.; II, 50-70% VO_2 Max.; III, greater than 70% VO_2 Max. Local signals dominate all three levels, and the percentage of VO_2 Max. is always proportional to tissue oxidative demand. The transition from levels I to II corresponds to changes in ventilatory responses from hyperpnea to isocapnic buffering. Levels II-III represent changes from isocapnic buffering to respiratory compensation for metabolic acidosis. Minute ventilation is at it's most potent at this level.

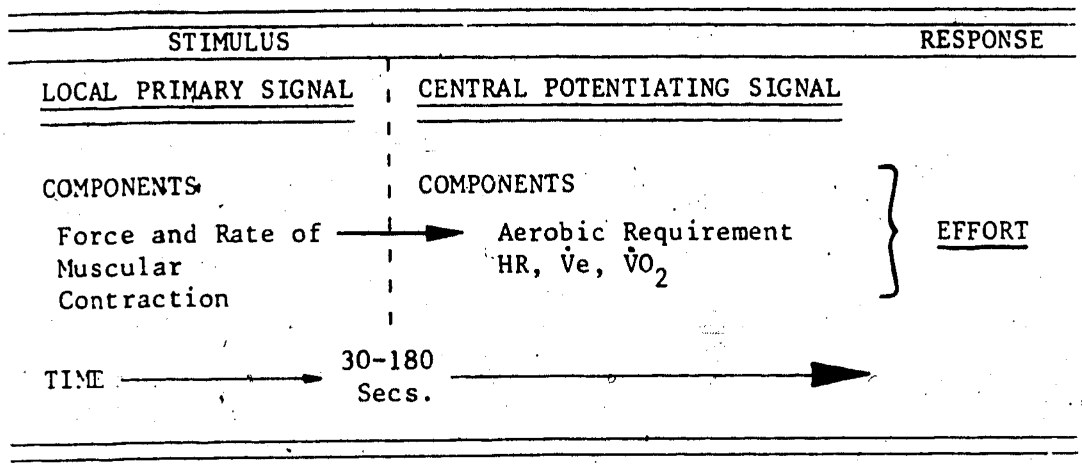


Figure 2.4 The relative contibution of Central and Local cues to RPE as a function of time (Robertson, 1982)

			RELATIVE CONTRIBUTION		
			CENTRAL		LOCAL
LEVEL	SYMPTOMS	METABOLIC INTENSITY	$\dot{V}_E$	% $\dot{V}O_2$ MAX	
I	MOVEMENT AWARENESS	< 50%	LIMITED	PROPORTIONAL	DOMINANT
II	DISCOMFORT/TOLERANCE	50-70%	MODERATE	PROPORTIONAL	DOMINANT
III	NOXIOUS PAIN AVOIDANCE	> 70%	SIGNIFICANT	PROPORTIONAL	DOMINANT

Figure 2.5 The relative contribution of Central and Local cues to RPE as a function of exercise intensity (Robertson, 1982)

The above models summarize some of the findings reviewed in this section. Differentiated RPE may thus give some clue as to the integration of RPE over time, and the potency of cues under certain circumstances. Mihevic et al. (1982) for example, found evidence to suggest that local or overall RPE may reflect relative metabolic demands; central RPE is affected by the absolute metabolic cost of the exercise. This data supports Robertson's (1982) model (figure 2.5) since VO_2 (a potential central signal) is proportional to the absolute aerobic requirement of the tissues. However, it was also suggested by Robertson (1982) that relative VO_2 (%VO_2 Max.) was a more potent signal than absolute VO_2; this area should be investigated further.

2.2.6 FURTHER PHYSIOLOGICAL FACTORS INFLUENCING RPE

2.2.6.1 Training

Skrinar et al. (1983) mentioned that prior to their study, five published works had attempted to investigate the longitudinal effects of training. Most of these have been on males only. Mihevic (1981)has suggested that RPE would be expected to parallel the physiological responses to training. Absolute exercise should be perceived as more effortful for the unfit individual in correspondence to the greater relative strain. However Morgan's (1978) findings (discussed in the psychological section) on elite and non-elite athletes showed that the RPE's found on an absolute exercise test, were not as expected and involved more than physiological input. Mihevic's (1981) view has been supported by Linderholm (1967, cited in Patton et al. 1977), Docktor and Sharkey (1971), Ekblom and Goldbarg (1971) and Knuttgen et al. (1973) who all found lower submaximal heart rates and parallel reductions in RPE after training for a given level of both treadmill and bicycle exercise. Ekblom and Goldbarg (1971) also reported that when RPE was expressed in relative terms of VO_2 Max. and HR Max., no change was found. However, a lack of controls in both 1971 studies, means that results must be interpreted cautiously (Mihevic, 1981).

Patton et al. (1977) investigated the effect of 6 months training on both untrained (group 1) and training (group 2) soldiers. At pretesting these authors found that although the training soldiers had significantly higher VO_2 Max. and lower heart rates on an absolute treadmill test, RPE was similar for both groups. These findings suggested that RPE is related to 'absolute' and not 'relative' work (compared to suggestions cited earlier). After training however, both these groups showed lower HR's and RPE's on the submaximal test, although again no differences were found between the groups. Patton et al. (1977) suggested that the perception of the intensity of exercise workloads was not reflected by differences in aerobic power due to training, when assessed on a cross-sectional basis. These authors posited that RPE changed as a function of training on a longitudinal basis.

Skrinar et al. (1983) attempted to investigate the effects of training on RPE and stress marker hormones using an intensive 6-8 week exercise program with women (n=15). Using the differentiated RPE method, these authors investigated the changes in RPE and physiological stress markers with training. Training resulted in an overall increase in VO_2 Max. of 19% and a decrease in central or overall RPE; however, leg RPE slightly increased. Stress markers of lactate, epinephrine and norepinephrine showed significant correlations with RPE. In contrast to Ekblom and Goldbarg's (1971) findings the above authors found significant decreases in Central and Overall RPE after training at similar <u>relative</u> exercise levels. These authors speculated that this could be due to increases in cardiorespiratory performance.

Skrinar et al. (1983) suggested that the differences between their study and that of Ekblom and Goldbarg (1971) may have been due to gender differences in the subjects used. However, there were some differences in the training used by Ekblom and Goldbarg (Ekblom, 1969) and that used by Skrinar et al. (1983) even though the training was supposed to be similar. Therefore some of the differences found may have been due to the type of training used rather than due to gender.

Lewis, Thompson, Areskog, Vodak, Marconyak, DeBusk, Mellen and Haskell (1980), investigated the effect of differential training (arm and leg exercise) on RPE. The results showed decreases in heart rate (a central effect) during submaximal exercise with both trained and untrained limbs; however, decreases in RPE were only found during exercise with the trained limbs. These findings lead the authors to believe that reductions in RPE as a result of endurance training were probably the result of local metabolic adaptations in the trained muscles. These authors also speculated that training may lead to selective hypertrophy of muscle fibres and more efficient motor unit recruitment patterns resulting in a smaller number of motor units needed for exercise. The subsequent reduction in CNS demand may be reflected in a lower RPE. Carton and Rhodes's (1985) review mentioned that the duration, frequency and intensity of training of these earlier studies are quite varied. The question of how each of these variables affects RPE is unknown.

Methodological problems may affect results in training studies. Patton et al. (1977) have suggested that the differences in fitness between groups and the testing intensities used may not be great enough to elicit any perceptual differences. The demand characteristics of longitudinal training studies may also present a testing bias; RPE values may be expected to decrease as a result of training (Morgan, 1977). Increases in efficiency in performing a task may be reflected in lower HR, RPE or VO_2 at submaximal levels, even though VO_2 Max. may not have increased (Patton et al., 1977). Docktor and Sharkey (1971) also warned that habituation or familiarity with a test may result in decreased reports of RPE separate from any fitness gains with training. Mihevic (1981) has also warned that the type of scaling method used may also give rise to testing bias, suggesting that the Borg scale (1970) may not be an appropriate instrument for assessing differences in fitness and RPE. Mihevic (1979) reported a significant difference in perceptual exponents for an absolute work test between groups of women varying in fitness when perceived effort was measured by magnitude estimation; however, this difference was not reflected in perceived exertion scores measured by the Borg scale. This experiment also investigated the effect of some psychological parameters on RPE. Mihevic found that psychological variables could not explain a significant amount of variance in the RPE scores, but the perceptual variance measured by magnitude estimation did seem to be influenced by psychological variables. Interestingly enough, psychic vigor and tension were most important in highly fit subjects, extraversion and tension were most influential in low fit subjects. Mihevic (1979) concluded that RPE and magnitude estimation may assess different portions of perceived exertion. Borg (1972, cited in Mihevic, 1981) however, did not find any differences in perceptual exponents between groups of different levels of fitness. There seems to be some controversy around this point.

Summary of training

Several unresolved issues are present in the area of training and perceived exertion. Is absolute work perceived as being the same for groups differing in fitness? Does RPE represent absolute or relative work stress? Are the separate factors involved in differentiated RPE affected differently by training? Does the type of training involved interact with changes in differentiated RPE?

Carton and Rhodes (1985) have questioned the amount of reduction in RPE that is needed to be considered significant. These authors quoted Morgan's (1977) suggestion that a one or two point reduction in RPE represents a 10-20% change. Such differences may be significant in endurance events.

2.2.6.2 Catecholamines

Frankenhauser, Post, Norheden and Sjoeberg (1969) found a positive association between catecholamine excretion during exercise with an increase in RPE. Docktor and Sharkey (1971) also suggested that a decrease in catecholamine excretion following five weeks of training (n=5) may be reflected in the parallel decreases in RPE also found as a result of training. Mihevic (1981) has however suggested that methodological problems, such as the catecholamine marker used (vanilmandelic acid), may have confounded the results of Docktor and Sharkey's (1971) study. Skrinar et al. (1983) also found significant correlations between RPE and epinephrine and norepinephrine. Mihevic's (1981) review suggests that catecholamines may be a cue for RPE at higher intensities of work (i.e., 50-65% of MAP, Howley 1976). The increase in catecholamine concentration during exercise also show a similar positively increasing function to that of RPE.

It should be noted however that epinephrine is associated with emotional arousal, and may be a cue when a subject is being tested at lower exercise intensities, but is also emotionally aroused. Frankenhauser et al. (1969) also noted the differential responses of epinephrine and norepinephrine to exercise. These authors concluded that epinephrine secretion reflected the mental stress or unpleasantness of the task. Therefore this marker might be useful in assessing a subject's perceptions of a stressor such as exercise. The use of such a marker might also be a method to investigate the effect of task aversion (Kinsman, Weiser and Stamper, 1973) on RPE.

Although catecholamine excretion may influence RPE the methods of monitoring the integration of the different catecholamine responses remains unclear (Mihevic, 1981).

2.2.6.3 Skin and Core Temperature

Pandolf et al. (1972) related core temperature to RPE during 30 minutes of continuous high intensity work. Noble et al.'s (1973) report, which seemed to be derived from Pandolf et al.'s study (Mihevic, 1981), indicated that skin and rectal temperatures accounted for the greatest variance in RPE in hot environments. The significance of this data is suspect due to the small sample size used (n=6), and the large variability in the variables measured. (Mihevic, 1981).

Carton and Rhodes (1985) have suggested that the experiments with temperature and RPE may not have been able to discriminate between perceived effort and perceived discomfort, this may cast some doubt on the construct validity of the measures used. Nevertheless, Pandolf et al. (1972) reported that their subjects were able to partial out thermal sensations from RPE. These authors found that subjects needed workload increments of 200 kpm in order to perceptually discriminate workloads; however, this workload level was not enough to alter sensations of discomfort. This data may support the notion that RPE and sensations of discomfort are separate constructs.

In summarising the effects of temperature on RPE, Mihevic (1981) proposed that skin temperature may not be an effective cue for RPE, although the regulatory processes involved in maintaining core temperature may provide inputs to RPE and account for the parallel responses found between these two variables. It is interesting to note that, anecdotally, individuals often cite sweating as a measure of exertion. The perception of sweat may therefore be a mechanism by which body temperature influences the perception of exertion.

2.2.6.4 Endorphins

The endorphins (endogenous morphines) are opiate-like substances, produced by the human body, which have been associated with analgesia and altered states of consciousness or perception such as the 'runners high', or dissociation (Callen, 1983; Morgan, 1985). The endorphins have been found to increase as a result of exercise and are thought to reduce the pain or discomfort associated with it. Shamas, Andrew, Bell and Cervenko (1984) have shown an association between endorphins and RPE; when the analgesic effect of endorphins was blocked by naloxone, ratings of RPE were higher than in a placebo condition.

It has been suggested that training results in an earlier onset and greater level of secretion of endorphins (Melchionda, Clarkson, Denko, Freedson, Graves and Katch 1984). This training effect could conceivably provide a theoretical basis for longitudinal decreases in RPE as a result of training. Wilmore (1968) has suggested that enhanced performance may be mediated by increased pain tolerance. Morgan (1978) has also suggested that highly trained elite runners can afford to associate with bodily cues due to their enhanced physiological capacity. Both of these phenomena may be explained by the attenuation of physical discomfort by an earlier and increased endorphin release due to training. However, this should be considered as speculative at present.

2.2.6.5 Blood Glucose

During prolonged exercise, glucose production may fall below the requirements of the working muscles and the central nervous system (CNS). Exercise may thus become subjectively more difficult due to CNS starvation, and difficulty in oxidising fats in the muscle (Brooks and Fahey, 1984). Although blood glucose may have a considerable effect in the perception of effort during prolonged work, the role of blood glucose does not seem to have been investigated in many of the past studies investigating RPE. Bell, Noble, Drash and Metz (1975) did find a lower RPE for long term exercise (3 hrs.) in which glucose was ingested prior to and during the run. This effect remained true even when compared to a placebo test. These authors suggested that feedback from the glucoreceptors may be consciously monitored.

2.2.6.6 Anaerobic Threshold (AnT) and Menstruation

Recently two studies have investigated the relationship between RPE and the anaerobic Threshold. Purvis and Cureton (1981) found that male and female subjects reported RPE's of 13.6 ±1.2 at their anaerobic thresholds. Since this corresponded with an RPE of 14 ('somewhat hard'), the authors suggested that this number could be used to prescribe exercise at the anaerobic threshold. It is interesting to note that these authors estimated AnT as the average time of the departure from linearity of VE and VCO_2 and the first abrupt or sustained rise in $FeCO_2$ (the fraction of CO_2 in expired air). Carton and Rhodes (1985) have cited this study as investigating the <u>aerobic</u> threshold, there therefore seems to be some controversy on terminology which should be resolved. Skinner and Mclellan (1980) have described two ventilatory 'break off' points termed 'aerobic' and 'anaerobic' threshold. Aerobic threshold refers to the first point where there is a nonlinear increase in VE and VCO_2, and an increase in FeO_2 (the fraction of oxygen in expired air) without a decrease in $FECO_2$, blood lactate also rises from a baseline value of 2 $mMol.l^{-1}$. Anerobic threshold refers to a decrease in $FeCO_2$ and marked hyperventilation, plus a sharp rise in blood lactate from 4 $mMol.l.^{-1}$. Using Skinner and Mclellan's (1980) terminology it seems as if Purvis and Cureton (1981) were describing the aerobic threshold. It would seem to be desirable to have a recognised definition for these constructs if RPE is being used as a method of monitoring training intensity, particularily as aerobic threshold is estimated to occur at 40-60% VO_2 Max. and anaerobic threshold between 65-90%VO_2 Max. (Skinner and Mclellan, 1980).

Stephenson et al. (1982) investigated the effects of AnT and menstruation using a 9-point scale. Again this study appears to be referring to 'aerobic' threshold. This study showed no change in RPE at any day during the menstrual cycle. The authors concluded that this evidence supported the use of female subjects with normal menstrual cycles in psychophysical studies without regard to cycle phase. The same study found that AnT was not affected by cycle day. This data is important in view of the fact that female subjects were used in the present study.

Higgs and Robertson (1981) have shown data contrary to Stephenson et al. (1982). These authors demonstrated that during intensive work (100%VO_2Max.) RPE was higher and work capacity lower during the pre-menstrual and menstrual phases as compared to mid-cycle. It is interesting to note that these effects were not seen at a lower exercise intensity (90%VO_2 Max.).

The literature is equivocal with respect to the effect of menstruation on athletic performance (Higgs and Robertson, 1981). Increases in RPE as a result of menses may be a result of both psychological and/or physiological processes. Possible mechanisms accounting for increases in RPE are the symptoms associated with pre-menstrual tension (P.M.T.) such as anxiety, irritability, fatigue, lethargy or gastro-intestinal disturbances; however no etiology is known. Higgs and Robertson (1981) speculated that the unpleasant effects of menstruation may be overcome by high levels of intrinsic motivation (often present in high-performance athletes). This may possibly explain the inconsistent findings on the effect of menstruation on elite performance.

2.2.6.7 Time of day, Circadian rhythms and Sleep Deprivation

The research findings on RPE and time of day seem to be sparse and equivocal. Faria and Drummond (1979) found that RPE's were affected by the time of day. Exercise at 2.00 a.m. and 4.00 a.m. was perceived to be harder than during the day. Contrary evidence has been shown by Reilly, Robinson and Minors (1984) who found no differences in RPE as a result of time of day when 10 male athletes exercised to exhaustion at different times of the day on separate days. The testing times of 0300, 0900, 1500 and 2100 hrs were randomly assigned. Reilly et al. (1984) suggested that RPE changes with time of day may be related to the type and intensity of work being used. Thus high intensity steady state exercise may show an effect of time of day, whereas incremental exercise to exhaustion may not.

Carton and Rhodes (1985) and Pandolf (1983) both cite equivocal findings in regards to the relationship of sleep deprivation and RPE. The two studies found evidence to both support and reject any effect of sleep deprivation on RPE. Myles (1985) however, found evidence to suggest that sleep deprivation caused increases in RPE during exercise bouts which [illegible] more than a few minutes in length. Sleep deprivation did not seem to affect R[illegible] exercise of short durations (<30secs.).

2.3 PSYCHOLOGICAL FACTORS INFUENCING PERCEIVED EXERTION

Pandolf et al.'s (1975) model of the levels of subjective reporting (See figure 2.3) implied that psychological factors such as task aversion (wanting to do something else), and motivation (drive and vigor) may have an input to perceived exertion. Pandolf (1983) also suggests that some psychometric variables such as neuroticism, stability, extroversion-introversion may also affect subjective reporting. Other authors have suggested that attributions, self-perception and anticipated task duration may also be involved (Rejeski, 1981). Dissociation strategies and hypnosis (Morgan, 1981; Morgan et al., 1983; Morgan and Pollock, 1977) have been used in attempts to manipulate perceived exertion. Robertson et al. (1977), suggested that a person's perceptual style (Stimulus Intensity Modulation), or level of field-dependance (Robertson et al., 1978), may also be implicated in RPE.

It seems that the perception of a stressor (e.g., exercise) is highly individual in nature. Thus the perception of exercise stress seems to be mediated by the individual's existing cognitive structures and coping capabilities (Smith, 1984).

2.3.1 PSYCHOMETRIC DATA

Morgan (1973) reported the findings of several studies examining the relationship of psychometric variables on perceived exertion. The measures involved were the Eysenck Personality Inventory, Spielberger's State-Trait anxiety scale, a somatic perception scale, and Lubin's Depression adjective checklist. Fifteen subjects were presented with four workloads in random order, and asked to rate their exertion by magnitude estimation. The results indicated that 89% of the ratings were accurate, although eight errors in perceived load were made. With one exception all of the subjects who made errors were either neurotic or anxious. The one subject who committed most of the errors was anxious, depressed and neurotic (Morgan, 1973). The author suggested that anxious, depressed and neurotic subjects may lack the ability to interpret subjective sensations consistently; this may be associated with the autonomic arousal associated with these undesirable states. Morgan (1973), also reported that the working capacity of anxious/neurotics is low.

Interestingly enough, Morgan (1973) found a significant inverse correlation of RPE and extroversion. Extroverts reported lower RPE ratings at given workloads, and higher preferred work intensities. This agreed with Eysenck's prediction of extroverts having more pain tolerance, greater physical persistence (Alderman, 1974), and being 'perceptual reducers', (Morgan 1981). Somatic perception was also seen to be highly correlated with RPE ($r = 0.75-0.83$), (Morgan 1973).

Morgan (1981) found that personality variables only correlated at higher workloads; thus the effects of personality would be seen at higher power outputs where discomfort or pain is encountered. Morgan (1981) also reported <u>negative</u> correlations of state and trait anxiety, and neuroticism and RPE during constant work over 30 minutes. This conflicting evidence to Morgan's 1973 study may be due to the different exercise protocols used and suggests that RPE and psychological measures are correlated in a complex manner (Morgan, 1973). Further replication studies are needed to clarify this area.

Morgan (1973) and Morgan et al. (1976), also found hypnotic suggestion of hard work increased RPE at constant work loads. The changes in RPE were associated with heart rate (Morgan, 1973) and VE ($l.min.^{-1}$) (Morgan et al., 1976).

2.3.2 DISSOCIATION/ASSOCIATION STRATEGIES

Morgan and Pollock (1977) have identified two major types of cognitive strategies used by long distance runners, association and dissociation.

Association: occurs when athletes focus on bodily sensations to maintain awareness of physical factors critical to performance (Weinberg, Smith, Jackson and Gould, 1984).

Dissociation: is that state in which the pain, discomfort and boredom that often accompanies long distance running are blocked out by using various strategies to distract attention from sensory input (e.g., those cues that are used in RPE). Such strategies may take many forms including solving complex problems, singing to oneself, or repeating a mantra in time with footsteps (Weinberg et al, 1984). Sachs and Sachs (1981) also found similar strategies in ultra distance runners (100 mile road race).

Morgan and Pollock (1977) investigated the effects of cognitive strategies on RPE using elite and non-elite runners. They found that both groups perceived an absolute workload of 10 mph. the same, even though the physiological cost was relatively greater for the non-elite athletes. These similarities in subjective reporting were negated at a workload of 12 mph. as the less accomplished athletes reported higher RPE's. Not surprisingly, it may be that perceptual differences between individuals or groups are only elicited at higher workloads (Carton and Rhodes, 1985); however, it was found that the non-elite athletes used dissociation strategies to distract attention from the stress, which may have accounted for the differences found (Morgan,1981).

Morgan, Horstman, Cymerman and Stokes (1983), used a mantra as a dissociation strategy to study it's effect upon performance. The results showed an increase in endurance time with the strategy compared to a placebo group. Similar results were found in experiments using Benson's relaxation response. These authors hypothesized that the increase in endurance was related to enhanced tolerance of discomfort based upon the distraction from internal cues. RPE did not seem to vary between groups.

It may be that dissociation/association strategies thus may influence the perception of exertion, by either distraction or diversion of attention from bodily cues (Rejeski, 1985).

2.3.3 TASK DURATION

Rejeski (1981) noted that subjects suppressed their RPE's when they expected that an exercise test would be longer than it actually was. The task duration effect was found to be effective at moderate work intensities, but not at higher intensities. The latter finding led Rejeski (1981) to believe that when internal cues for RPE were strong, the effect of external factors (such as task duration) seemed to decrease. Rejeski (1981) therefore suggested that there might be a potential boundary where the effect of cognitive variables might be attenuated when the strength of internal cues becomes such that they override any cognitive influence.

Davies and Sargeant (1979) also felt that the knowledge of the type of exercise (short or long term) may affect subjective readiness and perception of the exercise.

2.3.4 PAST EXPERIENCE

Rejeski (1981) has noted that women tended to give higher RPE responses than men at the same percentage of their VO_2 max. It was suggested that this effect may have been due to a socio-cultural phenomenon, where women less often encounter fatigue experiences. Noble (1982) however, reported that gender differences occurred at absolute VO_2 values (females being greater than males), but that these differences disappeared when physical work was evaluated as a function of relative intensity (%VO_2max.). This data should be interpreted cautiously for two reasons. Firstly, females tend to have a lower VO_2Max. than males (Fox and Matthews, 1981), thus an absolute workload would represent a greater relative strain on a female, most likely resulting in the differences seen (see Noble, 1982). Secondly, the nature of the population was not specified in Noble's (1982) report; thus, differences in the populations sampled (e.g., athletic, normal, active) may affect the generalisability of these results.

Rejeski (1981) suggested that socialisation effects may exert their influence through ego involvement, males may attempt to deliberately suppress their actual feelings to appear better. The effect of ego involvement may have been present in Morgan's (1981) findings that successful and non-successful triallists for the U.S.A. Olympic wrestling team demonstrated similar RPE's at the same absolute levels of work. In this study the absolute level of work was considered to be relatively harder for the less accomplished athletes; however, the context of a trial camp may have lead the less-successful athletes to suppress their subjective reporting to appear more comfortable with the level of work. Carton and Rhodes (1985) suggested that the intensity of exercise used in this experiment (750 kpm. for 5 mins) may not have been sufficient to create perceptual discrimination between such high fitness groups.

2.3.5 PERSONAL ATTRIBUTIONS

Rejeski (1981) has suggested that personal attributions may effect perceived exertion. For example, effort ratings seem to be higher after success than failure. It has been suggested that by giving a lower estimate of effort after failure athletes may be using rationalisation to protect their self-concepts.

"If I try just a little harder the next time, then I should do better". (Rejeski 1981)

Rejeski (1981) also emphasised that the perceptual process is a very individual phenomenon, thus effort may be perceived as different concepts such as ability or power, "toughmindedness, or the capacity to endure duress, withstand pain or overcome great odds" (Rejeski, 1981). Individuals might also differ in their perceptions of what is 'hard' or 'easy'. Such differences in the perception of a construct would surely affect subjective reporting.

2.3.6 PERCEPTUAL STYLE

Robertson et al. (1977) investigated the notion that an individual's perceptual style may affect the subjective reporting of perceived effort. These authors investigated the effect of Stimulus Intensity Modulation (SIM) on perceived exertion. It has been suggested that the normal adult population can be divided into three groups according to their SIM styles, these are:

Augmenters: Those who avoid excessive stimulation

Reducers: Those who attenuate the intensities of sensation and compensate by seeking stimulation. This portion of the population are similar to Eysenck's extraverts (Morgan, 1981).

Moderates: Who are between these two groups.

This theory was prompted by earlier research by Ryan and Foster (1967) who suggested that athletic groups may have a greater pain tolerance than their non-athletic counterparts. Athletes were hypothesised to use sports as a source of extra stimulation. These authors found that athletes in contact sports were perceptual reducers.

Robertson et al. (1977) hypothesised that the perceived intensity of work is mediated centrally (in the CNS), and SIM style should be useful in predicting the direction of perceptual reactions to muscular exertion. Reducers should therefore have lower RPE ratings than augmenters at work of the same physiological cost; this hypothesis was supported by the results.

Robertson et al. (1978) also investigated the effects of the field-independance and dependance dimensions on RPE. A field-independant perceiver extracts and analytically processes salient cues independant of the surrounding perceptual field. Field-dependant perceivers are less tolerant of sensory deprivation, more tolerant of noxious stimulation and pain, seek stimulation and are more extroverted than field-dependant thinkers. These authors suggested that field-dependant thinkers should attenuate their perceived exertion similar to reducers: However, no differences were found between the two physiologically similar groups when they were asked to perceive their exertion during exercise at the same physiological cost (Robertson et al., 1978). The results also showed that field-dependance and independance were not related to augmentation and reduction. The previously mentioned fact that exercise at similar percentages of VO_2 Max. may not equate other physiological responses to exercise may have affected Robertson et al.'s (1978) results.

Further evidence that may refute the effect of the field dependance-independance dimension on RPE has been shown by Mangum, Hall, Pargman and Sylva (1986). These authors found a non-significant relationship (r=-0.12) between perceptual style and the perception of physical effort (PPE). It is interesting to note that PPE was defined as the difference in heart rate responses between a standard work task and the subject's attempt to reproduce that task, and was considered distinct from RPE as measured on the Borg scale. The difference between these two constructs was emphasised by a small correlation coefficient suggesting that PPE and RPE were measuring different constructs. Noble (1982) corroborated this finding when he suggested that the psychophysical processes involved in different techniques for estimating exertion may not be identical. In the light of this data it may not be correct to compare Mangum, Hall, Pargman and Sylva (1986) findings with the other literature in this field which may have used other RPE measurement techniques. With this argument in mind it should also be noted that Robertson et al.'s (1977, 1978) data was generated using a 9-point scale. Mihevic (1981) warned that the comparison of data from the 9-point and the RPE scales should be undertaken with caution due to the formatting differences of the two scales.

The above evidence suggests that perceptual style may influence the reporting of perceived effort in some circumstances.

2.3.7 MOTIVATION, TASK AVERSION AND EMOTION

Motivation and task aversion have been proposed as potential factors that may influence the perception of effort (Kinsman, Weiser and Stamper 1973, Pandolf 1983). Gerber, House and Winsmann (1972) used a motivational contingency during self-paced ergometry performed by six soldiers. This contingency used extra pedalling as a negative reward for slower performances. These authors then studied the effect of the contingency on RPE and performance and found that it had no effect on either parameter.

The above findings are however in direct contrast with the results found by Kircher (1984). She used purposeful (rope-jumping) and purposeless (jumping in place) tasks as the two experimental treatments. On the basis that the 'purposeful' activity was intrinsically motivating for the subjects, Kircher found that RPE was lower for the motivated condition compared to the purposeless task at work of the same intensity. Motivation may thus direct attention away from fatigue or effort cues (Kircher, 1984). However, it may be that the increased perceptual demands of rope jumping may have diverted attention away from the discomfort of exercise.

Additional support for motivational and task aversion input to RPE was found by Kinsman, Weiser and Stamper (1973). These authors derived an eighteen item Physical Activity Questionnaire (PAQ) to assess subjective symptomatology during prolonged exercise (36 mins ± 22 mins. (time 1), 36 mins. ± 24 mins. (time 2). Three major symptom clusters appeared during the derivation of this questionnaire; fatigue, task aversion and motivation. Motivation was defined as activation or level of arousal, task aversion was defined as discomfort or disinclination to continue. These authors maintained that subjective changes during exercise can be grouped into unique clusters that can be reliably measured. Kinsman, Weiser and Stamper's (1973) findings were adapted and utilised in the differentiated RPE model (Pandolf, Burse and Goldman, 1975) which was discussed earlier.

Rejeski (1981) suggested that motivational input may not affect RPE if physiological cues are intense (similar to the effect of task duration). The effect of motivation may not be generalisable across tasks since an individual's perception of exertion (i.e., as ability to withstand pain) may affect RPE.

Finally, Rejeski (1981) felt that RPE may have emotional antecedents. Affective cues are seen to be important precursors to cognition and may be internal (personal emotional states) or external (e.g., the affective response from significant others) in origin. Thus internal cues such as anger, or external cues may have some effect on RPE. Rejeski (1981) suggested that the effect of emotions on perceived exertion may be an interesting area for future research.

2.4 SUMMARY OF THE REVIEW OF RATINGS OF PERCEIVED EXERTION

The previous review was not meant to be an exhaustive search of the literature, even though it is quite comprehensive in scope. The Borg scale (1970) is the best instrument available to assess RPE, as it can integrate salient factors at either a differentiated or a 'superordinate' undifferentiated level (Kinsman and Weiser 1976). However, a problem with this scale is that it may violate the true growth of effort perceptions (which increase in a positively accelerating manner) by virtue of it's supposed linearity (Borg, Ljuggren and Ceci, 1986; Borg, 1982; Carton and Rhodes, 1985). Another problem may arise out of the level of measurement that the scale represents which may confound some of data analysis in past studies. However, no better alternative presents itself for this study.

A few points seem to be well established in the literature such as the concept of central and local factors in the input to RPE. However, the specific physiological variables involved and their potency as cues seems to be an area that is still disputed. Research methodology may be a confounding factor in the current literature; such variables as the scaling techniques, exercise modes, exercise protocols and small sample sizes used (e.g., most studies in Mihevic's (1981) review used less than ten subjects) may provide conflicting data.

Even if objective physiological data could be reliably associated with central and local factors other parameters such as cognitive strategies, psychometric variables or perceptual style may alter the reporting of RPE.

Rejeski (1981) seems to have been the first author to illustrate the extent of the factors that may have an effect on RPE. Rejeski described RPE as a social-psychophysiological construct which integrated the effects of personality, physiological cues, past experience, motivation, external cues etc. (Rejeski, 1981).

Perceived exertion is a complex construct which involves a broad spectrum of mediating variables. The above review is therefore intended to give a rationale for some of the factors investigated in the present study.

3. METHODS

3.1 SUBJECTS:

Twenty female subjects aged 18-30 years were recruited for the study. These subjects also took part in a diet and exercise study during the period when these data were collected. The subjects were arranged into two groups.

Group 1. Training group, N=12. In which the subjects were active participants in a 6 month running/jogging training program.

Group 2. Non-training group, N=8. The members of this group underwent little or no regular physical activity in the 6 month period (other than everyday activities such as walking to university or their place of work). Since this group was not selected at random from the same pool of subjects as the training group, it cannot be considered a proper 'control' group. This group will simply be referred to as a non-training group.

3.2 SUBJECT SELECTION AND SCREENING

The subjects were selected from respondents to several advertisements published in university publications: a student union newspaper and the staff periodical "Folio" magazine.

3.2.1 TRAINING GROUP.

The training group was selected from respondents to an advertisement for healthy females who wish to improve their fitness level through a six month program of running or jogging.

All respondents were interviewed by telephone by the two investigators (the author, and a fellow graduate student and runner). The telephone interview, consisted of informing the respondent of the high degree of commitment required for the program, and ascertaining the respondent's current activity level. Those respondents who trained for more than once a week, or who were regularily involved in physical activity (e.g., squash or racquetball) were excluded. It was also necessary to eliminate those people who expressed doubt at their ability to fully commit themselves to the program (e.g., due to reasons such as conflicting hours, or time).

Potential participants in the training study were then invited to a common testing day at the University of Alberta Fitness Unit for a brief fitness screening test. The purpose of this test was to further eliminate doubtful applicants and select those applicants who seemed to be capable of completing the 6 month training program.

At the pre-screening fitness test potential subjects completed the Physical Activity Readiness Questionnaire (PAR-Q), an informed consent form for the tests and a physical activity questionnaire (to assess current activity habits). Following the signing of the appropriate forms, a short test involving several fitness measures was performed. A more complete description of the measures is included later in this chapter.

The subjects were selected on the basis of the fitness measures, responses to the PAR-Q and the investigator's perceptions of their ability to complete the program. Selected subjects were then asked to discontinue any activity or training other than running to prevent the possibility of other types of activity confounding results and were requested to attend two orientation sessions. The first session was used to describe the training procedures, assess personality and obtain blood samples. The second session introduced the subjects to the use of the diet diaries utilised in the other component of the study.

The above measures were taken to ensure as homogeneous a group as possible, based on fitness and previous activity.

3.2.2 NON-TRAINING GROUP.

The non-training group was picked from respondents to advertisements placed in the same publications as the training group. It was hoped that a similar population would be represented in both training and non-training groups. It can be argued however, that active and inactive people represent two different sub-populations. Physiological similarities were assessed at the pre-testing stage; however the psychological differences between the two groups were beyond the scope of this study.

The advertisements requested healthy males and females not currently involved in regular physical activity, other than "normal" daily habits. The non-training participants were requested to complete some diet diaries for a "Training and Diet Study", and to participate in some fitness tests at various specified times (0, 3, 6 months of the study).

Financial remuneration ($ 10 per diary) was offered to the non-training subjects upon completion of the diet diaries.

As with the training subjects, respondents to the advertisements were pre-screened by telephone to determine their suitability. Respondents involved in regular physical activity (defined as exercising more than once a week), were not considered admissible to the study.

Suitable applicants were then asked to attend an interview in which they completed the PAR-Q. If there was any inconsistency between the telephone answers, interview information and PAR-Q, the applicants were questioned and withdrawn from the study if deemed inappropriate. Suitable applicants were then asked to attend two orientation sessions described below.

3.3 PROGRAM INCENTIVES

Non-training subjects were paid for completing diet diaries, and were provided with free fitness testing at 0, 3, 6 month intervals. Training subjects were asked to provide their own financial motivation, to maintain incentive and to maintain participation in the study once started (see Dishman, 1984). This incentive was a deposit of $100.00. Fifty percent of which would be returned upon successful completion of the study. Training participants were informed of the possible consequences of dropping out of the study, and they signed a "contract" agreeing to the conditions of the deposit. The trainees also agreed to donate fifty percent of their deposit towards research expenses. It was emphasised that the potential costs of exercise testing far outweighed this donation. A full refund was provided in cases of injury, or mitigating personal circumstances. (See Appendix A for consent forms).

In addition to the above incentive, trainees were entitled to a 20% discount at a local sports goods store which had been negotiated by one of the investigators. It was hoped that this discount would encourage the use of appropriate running equipment. The discount lasted for as long as the participants remained in the study.

3.4 GROUP ORIENTATION MEETINGS

The schedule for group meetings was as follows.

1 Both non-training and training subjects attended a 'diet diary' orientation session.

2 Controls attended a session to complete personality questionnaires, and consent forms. A post-test meeting was also attended to complete a second personality test.

3 Trainees Meetings:

Trainees attended a meeting to be introduced to the training program and the purposes and requirements of the study. At this meeting various consent forms were signed, one of which informed the subjects of potential risks and benefits [illegible]ing (e.g., injury, fitness, enhanced psychological well being). (see Appendix A).

The trainees then completed various questionnaires for the diet study, and a personality questionnaire. Subjects were assured of the confidentiality of the results, and the need for integrity in completing the questionnaires.

Trainees also attended a final post-test meeting (at six months) to complete a second personality questionnaire.

3.5 TESTING PROCEDURES

Training subjects were required to complete a pre-sreeening test session. Once both training and non-training subjects were chosen all subjects were required to undergo a series of tests which followed the schedule described below.

All subjects were tested at three points (pre- (0 month), mid- (3 month) and post- (6 month)) during the training study for some variables, pre and post for others. The descriptions of the testing procedures are organised under the headings:

1. Pre-screening Measures

2. Test Associated with the Treadmill Test

3. Other Tests.

3.5.1 PRE-SCREENING TESTS FOR TRAINING APPLICANTS

A twelve minute sub-maximal bicycle test was used to estimate cardiovascular endurance. The equipment used involved a Quinton electrically-braked cycle ergometer to deliver the physical work and a Sport Tester to assess Heart Rate during the test. The exercise protocol involved an increase in resistance every four minutes in order to raise the subjects heart rate to the following levels: 110-120 beats per minute (bpm) for minutes 1 to 4, 120-140 bpm for minutes 5 to 8, 140-160 bpm for minutes 9 to 12. Maximum aerobic capacity was estimated by the Astrand Nomogram, (Astrand and Rodahl, 1977) A submaximal test of aerobic power was used for safety reasons, since the applicants were unknown to the investigator, and also to save time and expense, (Thoden, Wilson and MacDougall, 1982).

Skinfolds were taken at four sites to estimate percent body fat. A sum of skinfolds was calculated for each subject. The procedure is as outlined in the Canadian Standardised Test of Fitness operations manual, (Government of Canada, 1984). Height and weight were also measured.

This test was carried out as a pre-screening test only.

3.5.2 TREADMILL TESTING PROCEDURES AND ASSOCIATED MEASURES

The treadmill tests were performed at the pre, mid, and post tests. However, the initial treadmill test was seen as being inappropriate for later testing. Some subjects managed to continue for 20 minutes on the initial test, and it was believed that these subjects may have incurred fatigue before reaching VO_2 Max. (Thoden et al., 1982). The problem of discontinuing the test due to fatigue before reaching VO_2 Max., could have potentially affected later treadmill tests as it was predicted that the training subjects would increase their work capacity due to the training program. For this reason the treadmill protocol was altered for the mid and post treadmill tests so that subjects would reach VO_2 Max. before fatigue. Due to this modification, it was felt that perceived exertion may have been affected by the dissimilarity of the two tests (Robertson, 1982). Differentiated perceived exertion ratings were therefore obtained on the mid and post sessions only.

Therefore the initial treadmill test was considered as a further orientation session to a maximal treadmill test and the use of the RPE scale.

It should be noted that the effect of different treadmill protocols (Robertson, 1982) may confound any attempts to elicit ratings of perceived exertion at individualised percentages of VO_2 Max.

3.5.2.1 TREADMILL ORIENTATION PROCEDURES

Before the subjects were allowed to perform the pre-test on the treadmill, they were required to undergo a treadmill orientation session. The subjects were asked to walk or run on the treadmill at different speeds and slopes to familiarise themselves with the treadmill, and the testing procedures. It was hoped that the familiarisation session would reduce the level of pre-test anxiety which is commonly associated with treadmill tests (Cardus, 1978, p.84). Morgan (1973) suggested that anxious subjects may not be able to accurately perceive their exertional levels. It was hoped that the increased familiarity with the procedures would reduce this potential error.

The familiarization procedure consisted of the following steps:

i) The subjects were allowed to walk and jog on the treadmill at various speeds. The participants were instructed on the safety procedures (i.e., how to get on and off the treadmill and the appropriate use of hand signals).

ii) The subjects were then allowed to walk/run on the treadmill with headgear, and then with the Rudolph Valve in the mouth.

iii) The subjects were then introduced to the testing schedule (described below), and told to run until they wished to stop.

3.5.2.2 INITIAL TREADMILL PROCEDURE: PRE-TEST

The respiratory measures and heart rates were assessed directly using a motor driven treadmill, Beckman MMC, and Cardiotachometer. All participants (non-training and trainees) were asked to complete a modified, but standard graded exercise protocol on the treadmill (Thoden et al., 1982). The treadmill was chosen, since it was a similar task to the training mode used. The treadmill speeds for the protocol were taken from the orientation sessions, as speeds that all subjects could comfortably accommodate.

3.5.2.3 MID AND POST-TEST PROTOCOL

The mid and post-test was similar to the pre-test. The initial warm-up stage consisted of 1 minute walk/jog gradually increasing to the first testing stage - 2 minutes at 0° slope, and a speed of 5.5 mph. The speed was increased for the second stage - 2 minutes at 6.5 mph., 0° slope. From the 2nd. stage onwards the speed was held constant at 6.5 mph, but the grade of the treadmill was elevated 2° every 2 minutes until the test was terminated.

The subjects were first weighed in Kilograms (kg), and then prepared for electrodes. HR monitor leads and the head and mouth piece were then fitted. The subjects were then reminded of treadmill instructions (including RPE).

Criteria used for stopping the test were as follows.

1. A plateauing or slight drop in VO_2 Max. as work increases, or
2. Exhaustion of the subject (voluntary cessation) (Thoden et al., 1982).
3. Signs or symptoms of exertional intolerance (A.C.S.M., 1980).

The subjects were informed of their responsibility to inform the tester of their condition by hand signals.

Apart from standard questions during the progression of the test, (such as "How do you feel?" "Are you OK?") no other communication occurred between subject and tester. This procedure was adhered to in order to prevent the effects of differential motivation given to the subjects (Morgan et al., 1983). This seemed appropriate as motivation has been suggested as an influential factor in perceived exertion (Kircher, 1984; Pandolf, 1975, 1978, 1982).

The following physiological measures were recorded every 30 seconds: Heart Rate (bpm), VE l.min^{-1} (BTPS), VO_2 l.min^{-1}, VO_2 ml/kg.min^{-1}, VCO_2 l.min^{-1} (STPD). The ratios

$\%VO_2Max$. and VE/VO_2 were calculated from this data. No invasive measures were used. The equipment and calibration procedures used are presented in Appendix B.

3.5.2.4 RATINGS OF PERCEIVED EXERTION

Ratings of perceived exertion were measured using the Borg 15-point scale (Borg, 1970) and were taken in the last 30 seconds of each workload to coincide with the physiological variables of that 30 seconds. The subjects were given instructions to report central (CRPE), local (LRPE), and overall (ORPE) ratings when asked (see Appendix C for instructions).

The subjects pointed to a card showing the scale which was held within arm's length by a researcher. The subjects were advised to hold the treadmill bar if they felt unsteady when reporting RPE.

3.5.2.5 BODY COMPOSITION

Percentage body fat was estimated by the densitometry body density method. This method utilized the two compartment model (fat/non-fat), and used an equation to estimate body density (Brožek, Grande, Anderson and Keys, 1962). The equipment and methodology used are presented in Appendix B.

3.6 TRAINING PROGRAMME

3.6.0.1 ORIENTATION

The training program was outlined to the participants. The purpose of training progression was explained in simple physiological terms to provide subjects with a rationale for the program.

Subjects were also given information on suitable footwear and apparel. Details of the sports store discount were also explained. Advice on any footstrike problems was also offered to participants to aid in the choice of appropriate equipment.

3.6.0.2 TRAINING MODALITY

The primary modality used for training was running or jogging. Additional information on the program included correct warm-up procedures such as stretching exercises for running (Anderson, 1982). Sit-ups and push-ups were also included in the program for their value in maintaining muscular endurance to contribute to general fitness (Fox and Matthews, 1981).

3.6.0.3 INTENSITY, FREQUENCY AND DURATION OF TRAINING

The program was designed to allow the subjects to monitor their own training intensity without relying on expensive telemetry equipment. The procedure provided for testing the efficacy of a simple monitoring program that has been readily implemented in many fitness programs.

The training *intensity* was individualized for each subject, and was based on the Karvonen heart rate reserve method (HRR) (Fox and Mathews, 1981). The training intensity attempted to elicit 60-90% HRR.

Frequency, of training initially started at 3 times per week, increasing by one session a week every 2 months.

Duration of the exercise bouts started at 1.5 miles a week, the mileage was increased by approximately 5 miles a week each month, up to a total of 30-35 miles per week after 6 months.

Subjects were given a 'standardized' program format to follow; however, individual differences in the ability to adhere to the program were found. Subjects were thus encouraged to progress at their own pace.

It was intended that much of the program would be self regulated. Subjects were asked to log and graph their mileage each week, this was seen as a motivational device and a record of progress. (See Appendix D for actual schedule given to subjects).

3.6.0.4 TRAINING TIMES AND ENVIRONMENT

Subjects were assigned to lunchtime (12:00 noon) or evening (5:00 p.m.) training sessions. Eventually, it became clear that subjects had difficulty in maintaining the regular times, and so a flexible schedule had to be arranged. Thus subjects would train under the supervision of their trainer at least once a week and then make up their mileage on their own. It was hoped that the VO_2 Max tests and financial commitments would provide enough incentive to train. The fitness tests also provided an objective measure of the effectiveness of the actual training programs.

Training was initially conducted on a 200 metre indoor track, to avoid the inclement winter weather and the possibility of injury from running outdoors. Track running also aided the accurate assessment of training mileage. However, outdoor running was encouraged later in the program since the subjects reported it to be more enjoyable. It was decided to pursue this latter strategy to minimise the number of drop-outs from the study. In order to facilitate the outdoor running the investigators had accurately plotted several outdoor routes by using a measuring wheel. The routes varied from 3-4.5 miles in length and followed cross-country trails and paved road, utilising both hilly and flat terrain. Subjects were shown the courses and maps were provided.

3.6.0.5 TRAINING PERSONNEL

Training was monitored by the two principal investigators. The trainers alternated between each group on a weekly basis to control for any instructor bias. The trainers also met daily to discuss each training session, training progressions, and any problems that had arisen.

3.7 SUMMARY OF TRAINING AND TESTING SCHEDULE

A summary of the training and testing schedule is shown in Figure 3.1.

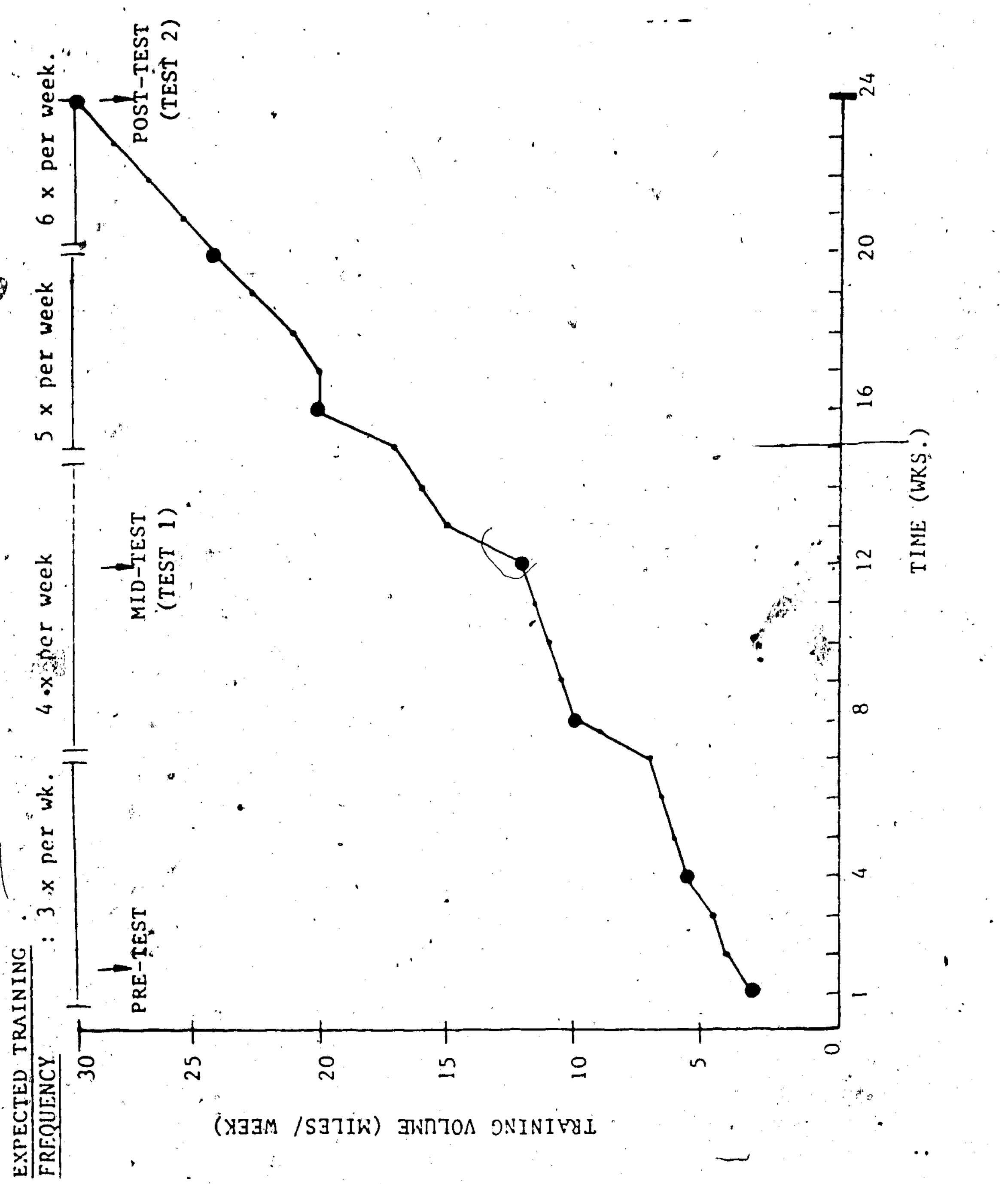


Figure 3.1 Training and Testing schedule for subjects

3.8 STATISTICAL ANALYSES

The data were analysed using the SPSSx package (Norusis, 1983). The level of association between the RPE measures and the physiological variables was assessed by Pearson product-moment correlation coefficients. Test-retest reliability was also measured using Pearson correlations, since this is the preferred method when assessing the same subjects on the same test on two different occasions (Ferguson, 1981).

Prediction equations for RPE were calculated using a stepwise regression method which used both forward and backward elimination processes (Norusis, 1983).

Finally, differences between groups, time or stages on all of the measured variables were assessed by a multivariate analysis of variance procedure (UANOVA, T. Taerum, Computing Services, University of Alberta, Canada.).

The minimum criteria needed to reject a null hypothesis of no differences between the means of the groups, stages or testing times was set at $p<0.05$ (Norusis, 1983). Any occurrences of more stringent levels of significance were also noted. The same criterion level was used for the Pearson correlations and the Regression analysis.

4.1 SUBJECTS

The physiological and anthropometric characteristics of the subjects at the pre-testing stage are shown in Table 4.1. It can be seen that the training group are slightly older, heavier and taller than the non-training group. The pre-test data for VO_2 Max., body weight and body fat was analysed by an analysis of variance. The analysis revealed significant differences at the $p<0.05$ level for body weight between groups; the training group weighing more than the non-training group (60.1 kg. and 55.1 kg. respectively). No significant differences were found between the groups for VO_2Max. or percentage body fat at the pre-testing stage. Details of the analysis are shown in Appendix E.

4.2 TRAINING EFFECTS

The volume of training achieved by the subjects is shown in Figure 4.1. It should be noted that subjects initially trained in excess of the required mileage; however, the training levels eventually failed to match the training schedule and never achieved the required goal of 30 miles per week. The inability to maintain the required training level during the latter stages of the investigation may partly explain the lack of significant increases in aerobic power which were found between the mid- (3 month) and post- (6 month) tests. The descriptive data for the physiological changes that occurred between the mid and post-tests are shown in Table 4.2.

The percentage increases in VO_2 Max. are presented in Table 4.3. It can be seen that the increases in VO_2 Max. as a result of training were more pronounced between the pre- and mid-testing sessions (22.0%). The increases in VO_2 between mid and pos[illegible]ry much smaller (3.4%). It should be noted that the RPE measures were take[illegible]d post sessions, thus the physiological effects of training may not have be[illegible] enough to elicit any changes in RPE.

Table 4.1 PHYSIOLOGICAL CHARACTERISTICS OF SUBJECTS AT THE PRELIMINARY TEST (PRE-TEST)

	AGE (*Yrs.*)	HEIGHT (*Cms.*)	WEIGHT (*Kg.*)	VO_2Max. (*ml.kg.min^{-1}.*)	% BODY FAT
TRAINING:					
M	26.4	163.6	60.1	35.9	26.8
s.e.	1.49	2.65	1.43	1.27	2.14
NON-TRAINING:					
M	22.1	158.2	55.1	35.5	26.4
s.e.	0.93	1.69	1.06	1.12	1.21

The notation for Table 4.1 and all other tables is as follows: M:mean; s.e.: standard error of the mean; n.s.: not significant; p: probability; ±: standard deviation.

Table 4.2 PHYSIOLOGICAL DATA FOR TRAINING AND NON-TRAINING SUBJECTS:MID AND POST TESTS

		WEIGHT (*Kg.*)	VO_2Max. (*ml.kg.min^{-1}*)	% BODY FAT
TRAINING (n=12)	**MID-TEST**			
	M	60.2	43.8	24.8
	s.e.	1.38	1.29	1.03
	POST-TEST			
	M	60.2	45.3	24.9
	s.e.	1.62	1.34	1.22
NON-TRAINING (n=8)	**MID-TEST**			
	M	56.5	37.5	26.2
	s.e.	1.38	1.66	1.69
	POST-TEST			
	M	56.5	36.7	26.5
	s.e.	1.44	1.23	1.19

Table 4.3 PERCENTAGE CHANGE IN VO_2 MAX. FOUND AT THE MID AND POST-TESTS

TRAINING:		
(n=12)	MID	POST
PRE	22.0	26.2
MID	-	3.4
NON-TRAINING:		
(n=8)	MID	POST
PRE	5.6	3.30
MID	-	-2.13

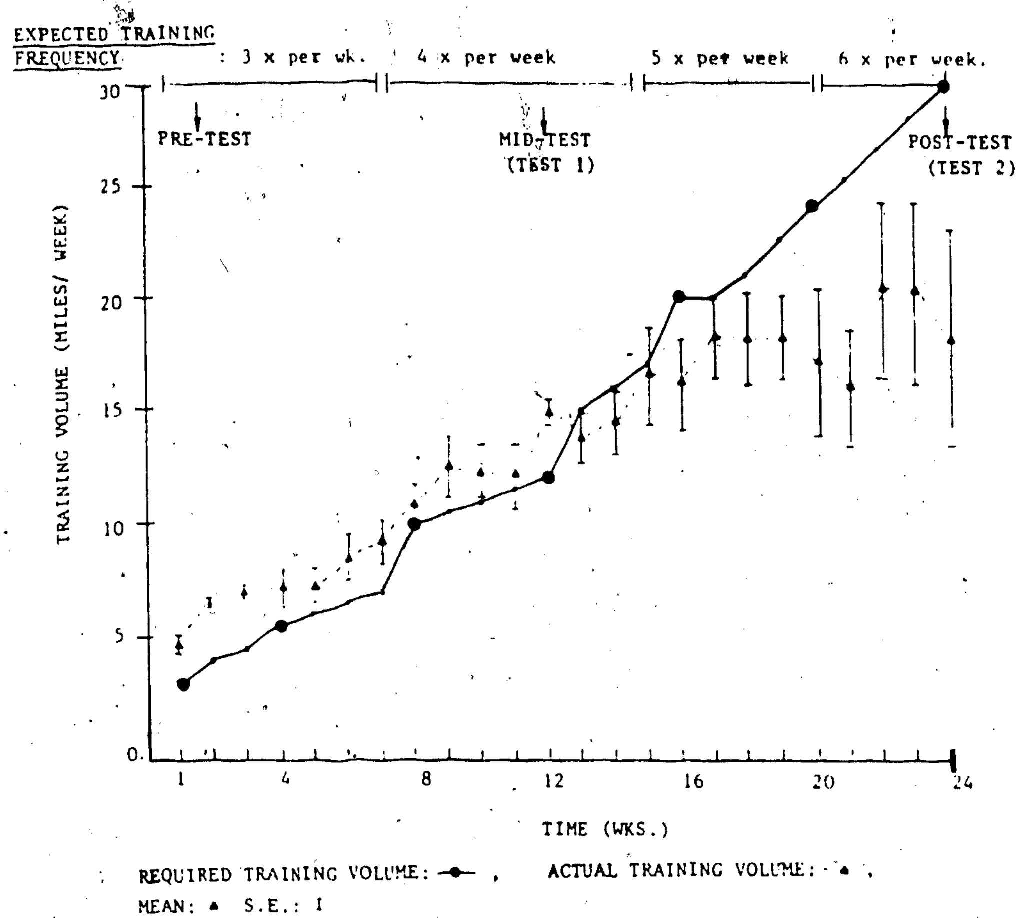


Figure 4.1 Graph showing training volume achieved by the subjects'

The group differences between pre, mid and post-tests for the three variables (VO_2 Max., body weight and body fat) were analysed by a two-way analysis of variance. The results of the pre-test analysis have already been described in section 4.1. The initial results of this analysis showed significant group differences ($p<0.05$) for VO_2 only, body weight showed a near significance ($p<0.07$) and no differences were found for body fat. A significant effect of time was found for VO_2Max., but not for the other variables. A group by time interaction was only found for VO_2max. A post-hoc test by Scheffe method of multiple comparisons revealed that VO_2 Max. had significantly increased ($p<0.05$) for the training group between pre (M=35.9 ml/kg.min^{-1}) and mid-tests (M=43.8 ml/kg.min.$^{-1}$), but not between mid (M=43.8 ml/kg.min^{-1}and post-tests (M=45.3 ml/kg.min.$^{-1}$). The training subjects therefore possessed significantly higher VO_2 Max. values at the mid and post-tests when compared to the non-training subjects.

The results for body weight showed that the initial (pre-test) differences between non-training and training groups were maintained throughout the six month period; however, no differences were found within each group as a function of time. No significant differences were seen for body fat between the groups at any stage of the six month period. The detailed analyses are shown in Appendix E.

Therefore the only significant effect of training was to increase the aerobic power of the training subjects between pre and mid-tests. Thus, significant differences in body weight and VO_2 Max. were already present between the groups before the investigation on RPE was conducted. These differences may have had some effect on the RPE measures taken, and will be discussed in a later section. The aerobic power of the training subjects was not significantly altered between mid and post-tests (the two perceptual testing points), this may also negate any longitudinal effects of training and RPE.

4.3 PERCEPTUAL AND PHYSIOLOGICAL DATA FROM THE MID AND POST TREADMILL TESTS

Since most of the non-training subjects only completed two of the test stages (0° slope, 5.5 mph and 6.5 mph) the training and non-training groups were compared on these two stages only. This analysis was conducted to compare the groups on similar test stages so as to avoid confounding factors such as different test durations and intensities which might have occurred when analysing other testing points (e.g. terminal RPE values). A summary of the means and standard errors for the different groups at mid and post-tests is shown in Tables 4.4 and 4.5. Due to difficulties in measuring heart rate, these values were not included in the analysis.

In order to ascertain any significant differences in the data with respect to groups, stages or test times the data was submitted to an analysis of variance (UANOVA, University of Alberta, 1986). The data was also subjected to the Bartlett-Box test for homogeneity of variance and analysis for normality (Norusis, 1983). The results suggested that the data did not violate the assumptions needed for analysis of variance; however, it should be noted that normality is a difficult concept to validate with such a small sample size (n=20). UANOVA appeared to be an appropriate test for the data. The initial analysis indicated some significant F ratios and probabilities which are shown in Table 4.6. The lowest criteria for significance was taken at $p<0.05$.

Significant main effects were found for group and stage for some variables. Significant interactions were also found for group by stage and group by time. No significant differences were found as a result of time (Table 4.6). Thus the training effect which would be expected to have manifested itself in the time analysis did not appear to influence any of the variables measured. Line graphs of the significant effects are shown in Figures 4.2 and 4.3.

A post-hoc analysis using Scheffés method of multiple comparisons (SPSSx) was performed on each significant difference shown for each variable. The results of the post-hoc

Table 4.4 PHYSIOLOGICAL AND PERCEPTUAL DATA FROM MID AND POST TESTS .TRAINING SUBJECTS

GROUP	VARIABLE	TEST 1 STAGE 1	STAGE 2	TEST 2 STAGE 1	STAGE 2
TRAINING N=12	CRPE	M: 7.9	10.3	8.6	10.9
		s.e. 0.51	0.71	0.51	0.51
	LRPE	M: 8.2	10.3	9.1	10.8
		s.e 0.55	0.72	0.68	0.58
	ORPE	M: 8.3	10.6	9.0	10.8
		s.e. 0.51	0.74	0.63	0.53
	VE, $l.min.^{-1}$	M: 56.7	68.4	56.1	66.8
		s.e. 3.19	3.54	2.29	2.38
	$VO_2 l.min.^{-1}$	M: 1.84	2.11	1.88	2.11
		s.e. 0.05	0.04	0.04	0.05
	$VO_2 ml/kg.min^{-1}$	M: 30.6	35.15	31.4	35.5
		s.e. 0.83	0.67	0.88	0.64
	VE/VO_2	M: 31.0	32.6	30.0	31.88
		s.e. 1.90	1.86	1.36	1.41
	$\%VO_2$Max.	M: 70.2	80.83	69.7	78.88
		s.e. 1.84	2.10	1.67	2.20
	VCO_2 $l.min^{-1}$	M: 1.85	2.26	1.73	2.12
		s.e 0.07	0.07	0.05	0.07

The variables are abbreviated as follows: Central, Local and Overall Perceived Exertion, **CRPE, LRPE, ORPE** respectively; Minute Ventilation, VE; Oxygen Consumption, VO_2; Respiratory equivalent for Oxygen, VE/VO_2; Percentage of Maximal Oxygen Uptake, $\%VO_2$ Max.; Volume of expired Carbon Dioxide, VCO_2.

Table 4.5 PHYSIOLOGICAL AND PERCEPTUAL DATA FROM MID AND POST TESTS, NON-TRAINING GROUP

GROUP	VARIABLE	TEST 1 STAGE 1	STAGE 2	TEST 2 STAGE 1	STAGE 2
NON-TRAINING N=8	CRPE	M: 11.0 s.e. 0.63	14.1 0.55	11.1 0.69	13.5 0.71
	LRPE	M: 11.1 s.e 0.72	14.0 0.68	11.4 0.68	13.5 0.79
	ORPE	M: 11.3 s.e. 0.75	14.38 0.59	11.5 0.73	13.9 0.77
	VE, $l.min.^{-1}$	M: 55.5 s.e. 3.03	69.2 3.72	54.5 2.43	70.9 2.50
	$VO_2 l.min.^{-1}$	M: 1.74 s.e. 0.06	1.94 0.07	1.66 0.06	1.88 0.07
	$VO_2 ml.kg.min^{-1}$	M: 30.9 s.e. 1.00	34.4 1.20	29.5 1.02	33.4 1.04
	VE/VO_2	M: 32.2 s.e. 2.19	35.9 1.91	32.9 1.44	37.8 1.09
	$\%VO_2Max.$	M: 82.1 s.e. 1.38	91.5 2.17	80.6 1.89	91.1 1.12
	$VCO_2 l.min^{-1}$	M: 1.74 s.e 0.08	2.18 0.09	1.76 0.09	2.24 0.11

Table 4.6 SIGNIFICANT F-RATIOS FOR ANALYSIS OF VARIANCE

VARIABLE	GROUP	TIME	STAGE	GRP/STAGE	GRP/TIME
CRPE	13.53†	n.s.	207.48*	n.s.	4.70‡
LRPE	11.77†	n.s.	112.19*	n.s.	n.s.
ORPE	11.77†	n.s.	143.67*	n.s.	n.s.
VE l.min.	n.s.	n.s.	303.55*	6.81‡	n.s.
VO_2 l.min.$^{-1}$	8.75†	n.s.	142.58*	n.s.	n.s.
VO_2 ml.kg.min.$^{-1}$	n.s.	n.s.	190.86*	n.s.	n.s.
%VO_2Max	22.57*	n.s.	160.06*	n.s.	n.s.
VE/VO_2	n.s.	n.s.	57.27*	12.28†	n.s.
VCO_2 $^{-1}$	n.s.	n.s.	209.83*	n.s.	n.s.

* $p<0.001$
† $p<0.01$
‡ $p<0.05$

Further details of the analysis are shown in Appendix F.

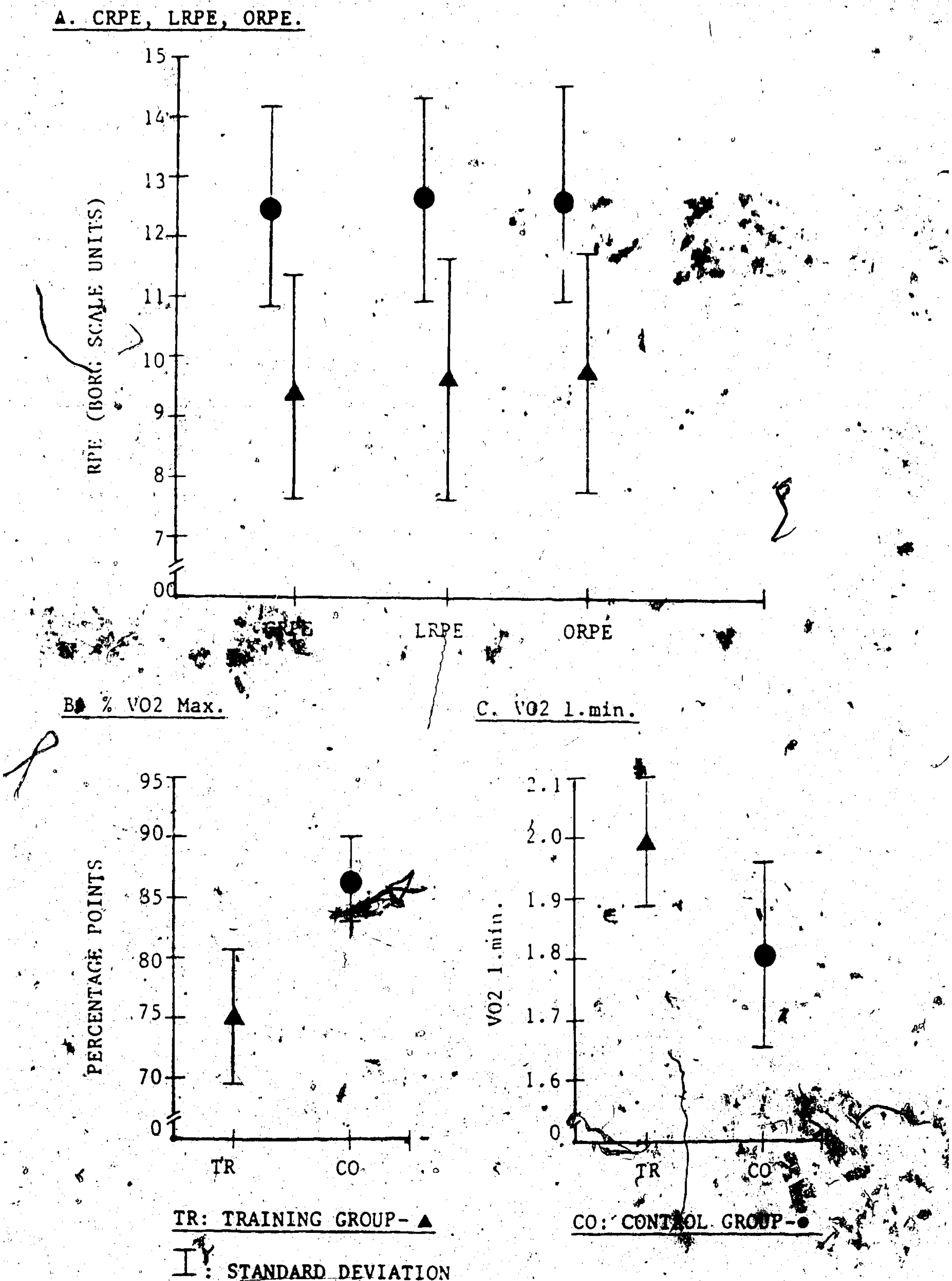
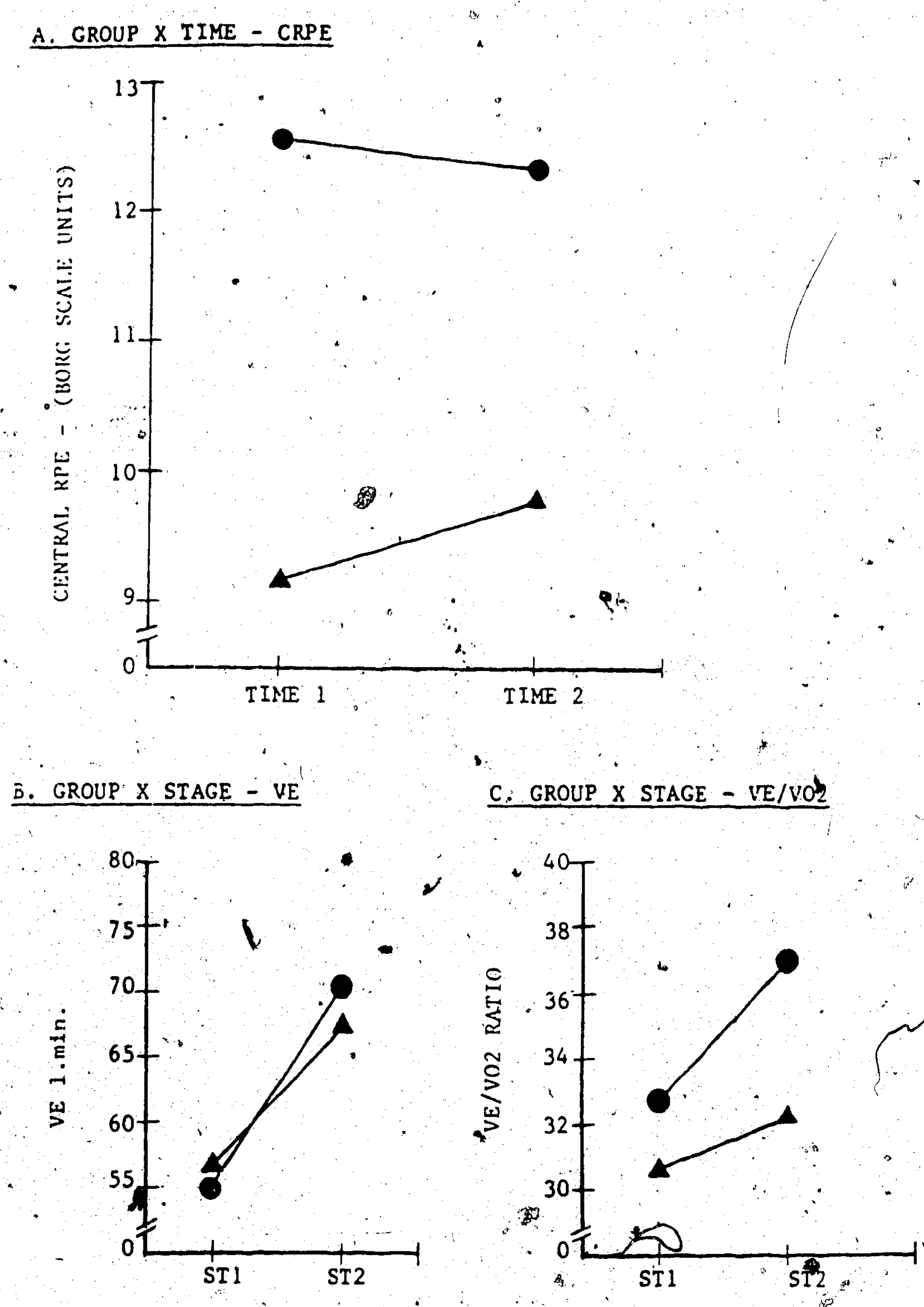


Figure 4.2 Variables showing significant group main effects



TIME 1: MID-TEST, TIME 2: POST-TEST
ST1: STAGE 1, ST2: STAGE 2
TRAINING: ▲, CONTROL: ●

Figure 4.3 Variables showing significant interactions analysis are shown below.

4.3.1 MAIN EFFECTS

4.3.1.1 GROUP EFFECTS

Differences between the training and non-training groups were seen in central RPE, local RPE, overall RPE, VO_2 l.min.$^{-1}$ and %VO_2Max.

A. Perceived Exertion

All three perceived exertion variables showed that the non-training group perceived the level of work to be consistently harder than the training group ($p<0.05$), (see figure 4.1a). The respective values were:

a) Training: CRPE (M=9.44 ±1.86); LRPE (M=9.58 ±2.03); ORPE (M=9.71±1.99).

b) Control: CRPE (M=12.44 ±1.67); LRPE (M=12.59 ±1.74); ORPE (M=12.72 ±1.81).

B. Percentage of VO_2Max.

The analysis showed that the non-training group were exercising at a higher percentage of their VO_2Max. when compared to the training group (see figure 4.2c). On average the training group were exercising at 74.99% VO_2 Max. (±6.13), whereas the non-training group were working at 86.33% VO_2Max. (± 3.52).

C. VO_2 l.min^{-1}

Results showed that the training group used more oxygen than the non-training group (training, M=1.99 l.min.$^{-1}$±0.114; controls, M=1.81 l.min.$^{-1}$±0.160). This difference was not seen when body weight was taken into consideration (i.e., VO_2 ml/kg.min.$^{-1}$), (see figure 4.1c and Table 4.6). The group differences are most likely accounted for by the significantly heavier weight of the training subjects.

4.3.1.2 STAGE EFFECTS

All variables showed significant differences between stage 1 and stage 2 of the treadmill test when values were collapsed across both tests (UANOVA). Values for all the variables were significantly higher during the second stage of the test (6.5 mph.). This data implied that the differences between the two stages of the test were of sufficient magnitude for physiological and perceptual discrimination (see tables 4.4 and 4.5).

4.3.1.3 EFFECT OF TIME

It was mentioned previously that no main effect was found for the perceptual test measures as a function of time. Any training effects would be expected to be mirrored by this parameter. It therefore seemed as if the subject's training program or the program adherence during the latter part of the six month period (mid to post test) was not of a sufficient to cause a significant physiological or perceptual effect.

4.3.2 INTERACTIONS

A further post-hoc analysis was conducted on the significant interactions (Table 4.6). Due to the number of comparisons, Bonferroni's correction factor was used to decrease the possibility of a type-1 error (Burns, 1984). Bonferroni's correction involves dividing the minimum level of significance ($p<0.05$) by the number of comparisons, thus since four comparisons were being made a probability of $p<0.0125$ (0.05/4) was required to show any significant differences between group by time or group by stage. The interaction means are shown graphically in Figure 4.3.

4.3.2.1 GROUP BY TIME INTERACTION

An interaction between group and time was seen for central RPE (CRPE) only. Training and non-training groups were found to be significantly different at the mid-test ($p<0.008$); however, these differences were not found at the post-testing time ($p<0.0394$). No significant differences were seen as a result of time within either group.

The interaction means are shown in Figure 4.3a. This figure shows that the differences between the groups at the mid-test were negated at the post-test since the training group slightly increased their perceived exertion, (M: 9.13 mid, 9.75 post) while the non-training group's CRPE slightly decreased, (M: 12.56 mid, 12.31 post). Possible reasons for the observed changes will be discussed in the next chapter.

4.3.2.2 GROUP BY STAGE INTERACTIONS

Differences were seen for VE and [illegible] (Table 4.6).

1. VE

The VE values significantly increased between [illegible] and stage 2 for both training and non-training groups [illegible]; however, no significant differences were found between the two groups at eith[illegible] interaction is shown in Figure 4.3b. The significant interaction was found due to the [illegible] training group having smaller VE values than the training group during stage 1, but higher VE values at stage 2.

2. VE/VO_2

The post-hoc analysis for VE/VO_2 revealed similar results to the VE measures. Highly significant differences were seen between stages 1 and 2 for both groups ($p<0.000$). (Figure 4.3c). However, significant differences were not seen between the groups at either stage, although the means appeared to be different (see Figure 4.3c). The reason for this lack of between-group significance may be attributed to the large error variance.

4.4 CORRELATIONAL ANALYSIS OF THE DATA

4.4.1 TEST RE-TEST RELIABILITY

A simple method of assessing the test-retest reliability of a given test, using the same subjects is by calculating the correlation coefficients of the two tests (Ferguson, 1981). The correlation coefficents for each stage between mid and post-tests are shown in Table 4.7.

The results in Table 4.7 show that the training group generally showed a higher level of consistency in their perceptions across the tests ($p<0.001$) when compared to non-training subjects. The test re-test coefficient for local RPE (LRPE) in the non-training group did not

Table 4.7 TEST-RETEST CORRELATION COEFFICIENTS FOR RPE MEASURES BETWEEN MID AND POST TESTS

TRAINING	STAGE 1	STAGE 2
CRPE	0.847*	0.877*
LRPE	0.709*	0.870*
ORPE	0.809*	0.900*
NON-TRAINING	**STAGE 1**	**STAGE 2**
CRPE	0.864†	0.713‡
LRPE	0.718‡	*n.s.*
ORPE	0.748‡	0.721‡

* $p<0.001$
† $p<0.01$
‡ $p<0.05$

reach significance (r=0.531).

4.4.2 CORRELATIONS BETWEEN RPE AND PHYSIOLOGICAL DATA

Pearson correlation coefficients were also calculated between each of the RPE and physiological measures. Significant correlations ($p<0.05$) between these variables are shown in Tables 4.8 to 4.11.

Results of the correlational analysis between RPE and the physiological variables indicated that separate clusters of physiological variables were associated with the RPE measures. The associations between these variables seemed to be very complex since different physiological variables were associated with each of the central, local and overall RPE measures. Different levels of association between these variables were also seen as a result of group, test stage (stage 1, stage 2) and test time (mid-test, post-test).

The correlations between the three RPE variables were nearly all significant beyond the $p<0.05$ level; the only non-significant association was seen between LRPE and CRPE in the non-training group (test 1, stage 2), (Table 4.10). The training group appeared to show more associations with the physiological data. VE l.min.$^{-1}$ and VE/VO_2 consistently showed significant positive correlations with the perceptual measures (Tables 4.8 and 4.9). An interesting finding was that VO_2 l.min^{-1} was always negatively correlated with RPE for both training and non-training subjects, (Tables 4.8 and 4.11)

The non-training group demonstrated less consistency in the correlations between physiological and perceptual data. VO_2 ml/kg.min.$^{-1}$ was the only measure that was associated with RPE (LRPE) in the first test; however, %VO_2 Max. appeared to correlate highly with CRPE and ORPE in the second test. VO_2 l.min^{-1} was again negatively correlated with LRPE and ORPE in the second test, (Tables 4.10 and 4.11).

Interestingly enough the ORPE measures were not as highly associated with the physiological data as CRPE or LRPE in the first test for either the non-training or training groups (Tables 4.8 and 4.10). This trend was altered on the second test where ORPE manifested higher correlations with the perceptual data, (Tables 4.9 and 4.11).

Complete correlation matrices for training, non-training and combined group data are shown in Appendix G.

4.5 PREDICTION OF RPE BY STEPWISE MULTIPLE REGRESSION

It was indicated previously that a stepwise regression procedure (SPSSx-STEPWISE) was conducted to calculate a possible prediction equation for RPE as an exploratory analysis. Since overall RPE is a combination of central and local factors and correlates significantly with both measures (r=0.666-0.988, see Tables 4.8 and 4.9), it was chosen as the dependant variable in this analysis. The independant variables used were all the physiological measures taken in the mid and post treadmill tests (i.e., VE l.min.$^{-1}$, VE/VO_2, VCO_2 l.min.$^{-1}$, VO_2 l.min.$^{-1}$, V[illegible]kg.min.$^{-1}$, %VO_2 Max.)

In order to satisfy the assumptions of normality and equality of variance an analysis of residuals was conducted (Norusis, 1983). The data did not seem to violate these

Table 4.8 SIGNIFICANT PEARSON CORRELATION COEFFICIENTS - RPE AND SELECTED PHYSIOLOGICAL VARIABLES, TRAINING SUBJECTS

MID-TEST	STAGE 1	CRPE	LRPE	ORPE
	CRPE	-	-	
	LRPE	.945*	-	
	ORPE	.929*	.899*	
	VE/VO_2	.528‡	.560‡	n.s.
	VO_2 l.min.$^{-1}$	n.s.	-.524‡	n.s.
	STAGE 2	**CRPE**	**LRPE**	**ORPE**
	CRPE	-	-	
	LRPE	.934*	-	
	ORPE	.985*	.968*	
	VE/VO_2	.593‡	.656†	.587‡
	VO_2 l.min.$^{-1}$	-.508‡	-.502‡	n.s.
	VE l.min.$^{-1}$	.497‡	.569‡	.497‡

* $p<0.001$
† $p<0.01$
‡ $p<0.05$

Table 4.9 SIGNIFICANT PEARSON CORRELATION COEFFICIENTS - RPE AND SELECTED PHYSIOLOGICAL VARIABLES, TRAINING SUBJECTS

POST-TEST	STAGE 1	CRPE	LRPE	ORPE
	CRPE	-	-	
	LRPE	.920*	-	
	ORPE	.964*	.967*	
	VE/VO_2	.672†	.770†	.793*
	VE l.min.$^{-1}$	.681†	.756†	.791*
	STAGE 2	**CRPE**	**LRPE**	**ORPE**
	CRPE	-	-	
	LRPE	.943*	-	
	ORPE	.988*	.978*	
	VE/VO_2	.702†	.663†	.706†
	VE l.min.$^{-1}$	.664†	.613‡	.675†

* $p<0.001$
† $p<0.01$
‡ $p<0.05$

Table 4.10 SIGNIFICANT PEARSON CORRELATION COEFFICIENTS - RPE AND SELECTED PHYSIOLOGICAL VARIABLES, NON-TRAINING SUBJECTS

MID-TEST	STAGE 1	CRPE	LRPE	ORPE
	CRPE	-	-	
	LRPE	.754†	-	
	ORPE	.912*	.920*	
	STAGE 2	**CRPE**	**LRPE**	**ORPE**
	CRPE	-	-	
	LRPE	n.s.	-	
	ORPE	.813†	.666‡	
	VO_2ml.kg.min	n.s	.789†	n.s.

* $p<0.001$
† $p<0.01$
‡ $p<0.05$

Table 4.11 SIGNIFICANT PEARSON CORRELATION COEFFICIENTS, RPE AND SELECTED PHYSIOLOGICAL VARIABLES, NON-TRAINING SUBJECTS

POST-TEST	STAGE 1	CRPE	LRPE	ORPE
	CRPE	-	-	
	LRPE	.706‡	-	
	ORPE	.933*	.844†	
	%VO_2Max.	.680‡	n.s.	n.s.
	VO_2l.min.$^{-1}$	n.s.	-.834†	-.751‡
	STAGE 2	**CRPE**	**LRPE**	**ORPE**
	CRPE	-	-	
	LRPE	n.s.	-	
	ORPE	.841†	.912*	
	%VO_2Max	.810†	n.s.	.752‡

$p<0.001$
† $p<0.01$
‡ $p<0.05$

assumptions and so the procedure was considered to be appropriate. Due to the small sample size used both groups were combined in this analysis, but were segregated within the sample by the use of a dummy variable (TRAING) which was set to 1 for the training group and 0 for the non-training group. The increased group size aided in testing for normality by plotting studentised residuals against the expected normal curve (SPSSx-RESIDUALS, SCATTERPLOT). Due to a further assumption that the scores used in the regression equation must be independant, the mid and post-tests and the two stages of the tests were analysed separately.

The results of the regression analysis for the mid-test data revealed that the only variable entered in the equation for stage 1 was the effect of training (TRAING): $R^2=0.3816$, s.e.$=1.917$, slope (b) -2.917. The [illegible] were similar for the second stage of the test: $R^2=0.411$, s.e.$=2.266$, (b)$=-3.667$. Th[illegible]cant F ratios, (0.0037 and 0.0023 respectively) indicated that the group effects were highly significant. These values support the significant group main effects found by the UANOVA analysis. These results indicated that there was a main effect of training on ORPE, where level of fitness and ORPE were inversely related.

The results obtained with the post-test analysis suggested that two physiological variables may be used to predict ORPE. In the stage 1 analysis, the first step revealed VE/VO_2 as a predictor variable: $R^2=0.3828$, s.e.$=1.951$, $b=0.325$. A second step showed that $\%VO_2$ Max. was also a predictor variable. Results from the second step for both variables were: $R^2=0.5237$, s.e.$=1.763$, $b=0.2478$ (VE/VO_2) $+ 0.2569$ ($\%VO_2$ Max.).

Analysis of the second stage showed that VE/VO_2 alone was the best predictor vari[illegible] $R^2=0.4591$, s.e.$=1.8586$, $b=0.3254$. The results therefore suggested that together VE/VO_2 and $\%VO_2$Max. could account for 52.4% of the variance in ORPE in stage 1 of the post test. VE/VO_2 alone could account for 45.9% of the variance in ORPE for the second stage of the post-test. The results of the regression analysis are shown in more detail in Appendix H.

The possible reasons for the different predictor variables between and within tests will be discussed in the next chapter.

5. DISCUSSION

5.1 TRAINING PROGRAM EFFECTIVENESS

The training program effects were most apparent between the pre and mid-tests. The subjects showed large increases in VO_2Max. (22.0%) over that three month period. These results compare favourably with other training studies which used jogging or running as the main exercise modality. For example Ekblom and Goldbarg (1971), reported increases of 15.5% in VO_2 Max. (l.min.$^{-1}$) after 8 weeks of training. Skrinar et al. (1983) measured increases of 19% in aerobic capacity with female subjects after completing a 6 to 8 week training program. This program was more intensive than the present study since the weekly mileage ranged from 20 miles in week 1, to 50 miles through weeks 5 to 8. Patton et al. (1977) showed increases of 9% in VO_2 Max. after 6 months of training with army recruits; however, the small changes seen may have been due to the initial fitness level of these subjects (M: 47.9 ml/kg.min.$^{-1}$). The present investigation found that the majority of the increases in fitness occurred in the 3 months of training that occurred before the physiological-perceptual testing, thus an increase in aerobic power of 3.4% was seen between mid and post-test. These results are similar to those of Skrinar et al. (1983) who showed a 6% increase in aerobic capacity between the mid and post-tests of their study.

Unfortunately the necessary change in treadmill protocol between the pre and mid-tests prevented the investigation of the effects of gains in aerobic power on RPE. Since the gains in aerobic power were not significant between mid and post-tests, the training subjects represent a stable 'fit' group against which the non-training group could be compared, at both mid and post-tests. The experimental situation is therefore similar to that of Patton et al. (1977) who compared groups of differing fitness both cross-sectionally and longitudinally. However, only one of the groups was involved in training in the present study.

The insignificant gains in fitness seen as a result of the second half of the training study (months 3-6, between mid and post tests), may have been a result of a number of factors. Firstly, the subjects may not have adhered to the training program as required. Analysis of the subject's training diaries indicates that this was indeed the case. Complete records of weekly mileage were kept by all subjects until the mid-test, after this point the quality of the record-keeping deteriorated with only 5 completed diaries being returned by week 24 of the study. (see Figure 4.1). Analysis of the weekly mileage indicated that the training actually achieved did not match the required levels after the mid-test (figure 4.1). The standard error of the mean of the training mileages also increased during the second half of the training program. This may have been due to the decrease in the number of training logs that were completed during this time period, and the increased inter-individual variability in the weekly mileages that were reported. Failure to uphold the required volume of training may indicate the potential difficulties of maintaining the motivation to train over such a long time period. This may be a particularily important factor in novice joggers. It is interesting to note that Skrinar et al.'s (1983) novice subjects managed to complete weekly mileages of 50 miles after only a month of training; however, these subjects were only expected to exercise for 6-8 weeks, so perhaps the duration of the study was not perceived to be as demanding as that of the present investigation. Skrinar et al. (1983) did not report the actual training levels achieved. Personal communication with several of the subjects after the study has suggested that those individuals who most closely adhered to the exercise prescription are those who have taken up running as a lifestyle activity. This may support the notion that the anticipated long-term duration of an activity may influence an individual's ability to adhere to a given program.

A second limitation of the training may have arisen from the training subject's reliability in monitoring heart rate accurately, or keeping to the prescribed intensity of exercise. The instructors reviewed this procedure on several occasions and the participants were encouraged to seek assistance if any problems in heart rate monitoring were encountered. The subjects seemed to be competent in taking heart rates. It was therefore hoped that any problems in monitoring exercise intensity would be avoided. However, since the subjects trained individually for much of the program it was not possible for exercise intensity to be checked on a regular basis. Heart rate monitors were not issued to the subjects either, these may have been useful in giving feedback about exercise intensity to the subjects. Skrinar et al. (1983) used telemetry equipment in their study, this may be a useful adjunctive method for regulating exercise intensity in future training studies.

A third and more plausible explanation for the small increases in aerobic power between mid and post-tests seen in both the present study and that of Skrinar et al. (1983) may be provided from the exercise physiology literature. Fox and Matthews (1981) have cited evidence suggesting that, initially, increases in fitness are very rapid in response to training; however, the rate of increase tends to slow after a few weeks of training and eventually reaches a plateau. de Vries (1980) explained that the rate of change in fitness is inversely proportional to fitness level, thus fitness gains are more difficult to achieve once a participant has made initial improvements. de Vries (1980) cited evidence to suggest that the rate of improvement slows down substantially after 6 weeks. Thus the mid-tests in both the present study and that of Skrinar et al. (1983) measured the dramatic improvements that resulted from the early stages of training. The later tests show the typical plateauing effect. The initial fitness gains would be expected to be large since both groups were relatively unfit. The early improvements seen in the present study were probably large when compared to other studies due to the low initial aerobic powers demonstrated by the subjects (M: 35.9 ml.kg.min.$^{-1}$).

The small fitness gains seen as a result of the second half of the training program prevent a complete investigation of concomitant changes in RPE as a result of aerobic power; however, a cross-sectional and longitudinal comparison of training and non-training subjects was possible. Since the two groups differed significantly in fitness at both testing times, they provide an opportunity to investigate the stability of RPE in different groups over time. This analysis might also examine any effects of training on RPE independant of any changes in aerobic power (such as increased pain tolerance, Wilmore, 1968).

Finally, the body fat data may have two implications. Firstly, the similarity in percent body fat of the two groups, may imply that the two groups did represent a similar population. It should be noted that the initial VO_2 Max data also indicated a similarity (Table 4.1). A second implication of the data in Table 4.2 was that the training had little or no effect on body fat. This second observation may have been due to the inefficacy of the training program, yet the fitness data showed a significant increase in aerobic power with training. A more plausible explanation may be that the training group increased their calorific intake as a response to the increases in physical activity, thus maintaining body fat at pre-training levels.

5.2 COMPARISON OF TRAINING AND CONTROL GROUPS

5.2.1 CROSS-SECTIONAL ANALYSIS OF RPE AND PHYSIOLOGICAL DATA

The perceptual and physiological data indicated that for both of the tests the control group consistently rated their perceived exertion higher than the trained subjects. (see Tables 4.4 and 4.5, and Figure 4.2). This effect was consistent between all the RPE measures. One surprising finding was that the oxygen cost of the work being performed was higher in the training group when compared to the non-training group; however, this finding might be explained by the significantly different weights of the two groups. Since the training group weighed more than non-training group at both tests (Table 4.2) this group would have to use more oxygen due to the weight-bearing nature of the task. The RPE's therefore seemed to be inversely related with VO_2, since the RPE scores were higher in a group that used less oxygen at each stage of the test.

The results showed that the non-training group were working at a higher percentage of their maximal aerobic powers during both stages of the tests (approximately 81% stage 1, and 91% stage 2) when compared to the more fit, trained group (approximately 70% stage 1, and 80 % stage 2). Therefore RPE seems to be positively related to the relative cost of the work being performed (e.g., $\%VO_2$ Max. rather than the absolute level of the work ($VO_2 l.min.^{-1}$).

When the data of both groups were considered together, an analysis of the relationship of RPE and $\%VO_2$Max. revealed some significant correlations between the two variables. The data from the first test revealed a significant relationship between CRPE and the relative oxygen cost of the work ($r=0.4128$, $p<0.05$, stage 1; $r=0.4055$, $p<0.05$, stage 2). LRPE and ORPE were approaching significance ($p<0.054$ to 0.085). However, the data taken during the second test revealed greater levels of association between all of the RPE variables and $\%VO_2$ Max. Thus during the first stage correlations (r's) of 0.6484 ($p<0.001$), 0.4810 ($p<0.016$) and 0.5753 ($p\leq0.004$) were found for CRPE, LRPE and ORPE respectively. Results for the second stage showed r's of 0.5567 ($p<0.005$), 0.4889 ($p<0.014$) and 0.5622 ($p<0.005$) respectively for CRPE, LRPE and ORPE (see Appendix G). It should be noted that the relationships between $\%VO_2$ Max. and RPE were not so strong when each group was analysed separately, (see tables 4.8 to 4.11). It may be that the range of values within each group was not large enough to allow a meaningful comparison.

It should be remembered that the value of r is influenced by both the variance of the data (Hopkins and Glass, 1978) and the sample size (Wilmore, 1968), thus the groups represented a smaller and more homogenous sample when analysed separately than when taken together. This factor might help account for the different values of r for RPE and a particular variable which are seen between the separate and combined group analyses. For further details of group variances see Appendix F.

Thus it seems that RPE shows a high level of association with the relative cost of the exercise being performed.

A further extension of the relationship between RPE and the relative cost of exercise would be to investigate the association of RPE to a given percentage of VO_2 Max. A preliminary analysis of the data from both groups of subjects implies that a RPE of 10.3 to 11.5 may be associated with work between 79 and 82.1% VO_2 Max. (see tables 4.4 and 4.5).

This data can be compared to that of Skrinar et al. (1983) who found that RPE's of 15.9 (CRPE), 16.0 (LRPE) and 16.1 (ORPE) were associated with workloads of 80%VO_2 Max. Thus the subjects in the present study found work at this exercise intensity to be less effortful than Skrinar et al.'s participants. The differences between the two studies may be explained by the different test protocols used since Skrinar et al. (1983) employed an hour-long test with successive 20 minute bouts at 60, 70 and 80% VO_2 Max. Since RPE increases as a function of exercise time (Mihevic, 1981) the higher RPE's at 80% VO_2 max. given after 60 minutes of exercise in the 1983 study are not surprising.

The concept of relating RPE to a given exercise intensity would be important if RPE is to be used as a method of prescribing exercise (for example Noble, 1982). In fact, Purvis and Cureton (1981) even suggested that training at an RPE of 14 would be suitable for training at the anaerobic threshold, which was found to occur at 60.1% VO_2 Max. ±7.8 (males), and 60.3% VO_2 Max. ± 7.7 (females). The relationship between %VO_2 Max. and RPE found in this study seemed to be quite stable across tests (see sections 4.4.1 and 5.3.1 on reliability of RPE), therefore it may be useful to use RPE as a method of prescribing exercise. However, it is debatable whether the RPE's elicited during a short term exercise bout (such as the one used in this study) would be of value in prescribing exercise of a longer duration (e.g., 60 minutes). Smutok et al. (1980) suggested that RPE's may be useful in prescribing exercise at intensities greater than 150 bpm., (80% HR max.); however using RPE's for prescribing lower exercise intensities may produce inaccurate and unreliable training heart rates (Smutok et al., 1980). This could be potentially dangerous if this method was used to prescribe exercise for cardiac rehabilitation patients (Noble,1982). Noble (1982) concluded that further research is needed before the use of RPE in exercise prescription can be recommended.

The results therefore indicated that RPE is directly related to %VO_2 Max. and is able to discriminate between two groups differing in fitness. Thus, individuals who are working at a higher percentage of their maximal aerobic power tend to perceive a given absolute workload as more effortful than those who are exercising at a lower level of their maximum capacity. This would be expected intuitively (Mihevic, 1981).

Further evidence supporting the relationship between %VO_2 Max. and RPE has been shown by Fleming, Weber, Goldfuss, Nixon and Kimbrough (1982). These authors found no difference in RPE between fit and unfit groups when they were tested at 60, 70 and 90% VO_2 Max. This supports Ekblom and Goldbarg's (1971) findings that differences in RPE found at absolute exercise intensities are negated when exercise is expressed in terms of a percentage of MAP.

It is also interesting to note that Central RPE was the RPE variable which was most highly associated with %VO_2 Max.; however, this data is in direct contrast with the findings of Mihevic et al. (1982), who found that central RPE was related to the absolute cost of work. The contrasts seen between the results of the two studies may reflect the different exercise protocols used. Mihevic et al. (1982) used a paradigm involving normoxic and hyperoxic conditions. CRPE was found to be higher in a condition in which the subjects exercised at 75% normal VO_2 Max. breathing 70% O_2; this condition represented the highest level of work achieved by the subjects. Due to the different nature of the tests it may not be realistic to compare the results. The relationship of CRPE with %VO_2 Max. is not surprising since CRPE represents cardio-pulmonary strain. It would also be expected that working at high levels of aerobic power would increase respiratory drive (and hence RPE) due to the buffering of H^+ ions which accumulate as a result of passing the anaerobic threshold.

This evidence supports the concept of RPE as reflecting relative exercise intensity as proposed by Ekblom and Goldbarg (1971), and other authors who found reductions in RPE as a result of training (see section 2.2.6.1). However, this data is in direct contrast with the findings of Patton et al. (1977), Mihevic (1979) and Morgan (1981), who found no differences in RPE between groups differing in fitness. Patton et al. (1977) suggested that their results may have been affected by the intensity of the work that their subjects were required to perform (75 to 81 %VO_2max.). Differences in fitness may only be reflected in

RPE scores at intensities higher than 80% VO_2 max. (which was the case in this study). Another factor influencing Patton et al.'s (1977) results may have been the small differences in fitness between the two groups (approximately 10% for both tests), which may have diminished the effects of fitness on RPE. It is interesting to note that the difference in VO_2 Max. across the two tests in the present study is about 20%. The large differences in fitness and the high intensity of the work being performed may account for the differences seen in RPE between the two groups in the present study.

Mihevic (1979) found no differences in RPE at any given workload on an absolute bicycle ergometer test between groups differing in fitness (using the Borg scale). The reason for the direct contrast between the present study and Mihevic's is unclear since the difference in fitness between the groups in Mihevic's study (36%) was even larger than that found here. One possible explanation may be that Mihevic used bicycle exercise which may have been unfamiliar to both groups; this may have confounded results. Since the training group in the present study were tested using a familiar task (running), this may have accentuated any differences in RPE between training and non-training groups. Mihevic's (1979) study was only reported in an abstract and so the training history of the subjects is not known. Another factor that may explain the difference seen between the two studies may be the exercise protocol used. Mihevic (1979) used workloads of 200, 400, 800 and 1000 kpm/min. for 1 minute per workload. Therefore the level of work used may not have been large enough to provide a basis for discriminating between the two groups.

Morgan (1981) also reported similarities in RPE between groups differing in fitness when exercising at lower workloads (10mph.); however, these similarities were negated at higher levels of work (12mph.). This data corroborates the findings that differences in RPE are probably most likely to be found at the higher relative exercise intensities.

Another factor that may have caused the differences between the two groups was the anticipated duration of the test. Rejeski (1981) cited evidence suggesting that subjects suppressed RPE's if they thought that a test was going to last longer than it actually did.

Since the training subjects may have expected to improve with training (Morgan, 1977), and run for longer on the test they may have subconsciously suppressed RPE values. However, this remains a speculative notion.

5.2.2 LONGITUDINAL ANALYSIS OF TRAINING AND RPE

The effect of time was only seen in an interaction between group by time (see 4.3.2.1). It has been suggested that longitudinal studies on training and RPE may be subjected to several artifacts such as increased fitness, familiarity with the test (Docktor and Sharkey, 1971), increased efficiency (Patton et al. 1977) or the expectancy of decreased ratings with gains in fitness (Morgan, 1977; Patton et al., 1977). The longitudinal effects of this study should be analysed with respect to these possible factors.

Firstly it should be emphasised that RPE did not change significantly between the two perceptual tests in either the training or non-training groups. It should be remembered however that the criteria for perceptual significance may not equate with that found statistically. Carton and Rhodes (1985) cited Morgan (1977) and emphasised that a change in RPE of 1 or 2 RPE units may be very significant in endurance events. The only statistically significant finding was the group by time interaction (see figure 4.3a and Tables 4.4 and 4.5), caused by a small increase in CRPE in the training group and a small decrease in the CRPE ratings of the non-training group. These differences ranged from 0.1 (CRPE, stage 1, non-training) to 0.9 (LRPE, stage 1, training), and may just reflect random error; however, a 0.9 point increase may be considered to be perceptually important and so possible reasons will be discussed.

The fitness of the two groups did not change significantly between the two tests (see Table 4.2), it also seemed as if the RPE ratings were unaffected by the training program. Thus the data cannot help identify the magnitude of fitness changes needed to manipulate RPE as a function of training. It is interesting to note that the subject's efficiency on the test did not change either since the oxygen cost of each stage of the test was the same for both tests within each group (Table 4.5). Efficiency may therefore be discounted as a possible confounding factor, although it has been mentioned in past training studies (Patton et al., 1977).

Habituation to the test ma[illegible] confounding factor. [illegible] subjects had all completed an initial treadmill test to exhaustion (using a different [illegible] used the Borg scale during this test. It was hoped that this process would lessen the effects of learning between the second two tests. Additionally the two perceptual tests were held 3 months apart which should also have diminished the effect of memory, although the subjects may have remembered their ratings from earlier tests. Decreased test anxiety between the two perceptual tests which may result from increased familiarity with the testing environment may account for the small decreases in RPE seen in the non-training subjects. Morgan (1973, 1981) has emphasised the importance of state and trait anxiety in regard to RPE; however, the relationship between these variables is uncertain at present (Morgan, 1981).

A further factor that may influence RPE in longitudinal training studies is the expectancy that exercise will become easier as a result of training. Morgan (1977) hypothesised that a typical reaction by a subject (s) giving RPE's in such circumstances may be as follows:

> They have asked me to rate the perception of my effort. It feels like it is about 11.5 to me right now (perhaps s rated it as 11, 6 months earlier), but I have been training for 6 months so I probably should give it a lower value. Yes, I will tell them 9.5. (Morgan, 1977, p. 273)

Morgan (1977) also alludes to the cognitive dimension involved in RPE when he suggested that subjects may wish to be "good" (sic.), and help confirm the experimenter's hypothesis. Since the training instructors were also administering the tests a further bias may have been present. The training subjects may have been trying to please the experimenters by perceiving themselves as being capable of doing more work as a result of training. This may have lead to the slight increases in CRPE seen in the training group. Although such ideas must be treated as speculation they are consistent with common patterns of cognitive behaviour which add a further dimension to an already complex situation.

Since the study was not blind, experimenter bias may also have been a confounding variable. The experimenters might have transmitted their expectations to the subjects, or even held the Borg scale slightly differently between tests and stages. An attempt was made to compensate for this potential bias by eliminating motivation from the test (Morgan et al., 1983), and by holding the scale in a consistent position. Nevertheless these potential biases cannot be ruled out.

The small increase in central RPE in the training subjects is an unexpected training effect that is independant of increases in aerobic power. It may be that these increases were due to an increase in associative thinking by these subjects. The phenomenon of association has been addressed in section 2.3.2 and refers to the focussing of attention onto the physiological sensations of the body (Weinberg et al., 1984). In a recent study on association and dissociation strategies Okwumbua, Meyers, Schleser and Cooke (1983) found that novice runners became increasingly associative over time (five weeks) as their physical ablilities increased with training. This may confirm Morgan's (1981) statement that a fitter person can afford to associate with his/her bodily cues since a given workload will represent less of a relative strain. Thus the need for dissociation is lessened in the fitter subject. It may be that the training subjects found that they could associate with the physiological inputs to the effort sense more easily as a result of training. This remains speculative.

Fatigue may be the final factor that increased the training subject's RPE during the final test. Teghtsoonnian et al.'s (1977) findings on fatigue have already been discussed (section 1.1). Fatigue seems to decrease RPE at lower exercise intensities, but increase RPE at higher workloads. Since work was being conducted at 70-80% VO_2 Max. fatigue may have influenced RPE. Skrinar et al. (1983) noted that local RPE increased as a result of intensive training, possibly as a result of joint or local muscle trauma, but overall and central RPE decreased even at the same relative intensities.

An increase in local muscular fatigue would have led to the recruitment of more anaerobic muscle fibres to maintain the required force (Fox and Matthews, 1981) which in turn may have increased VE to compensate for acidosis; however neither VE $l.min.^{-1}$ or LRPE changed as a result of training. Since the only RPE changes were seen in Central RPE, fatigue or soreness in the respiratory apparatus may have been a cue. The changes seen in the CRPE scores may have reflected the type of training undertaken. The duration and intensity of the training used (see section 3.6.0.3) would have stressed the central (cardio-pulmonary) component of the aerobic system (MacDougall and Sale, 1981). The training subjects may therefore have been more aware of their cardio-pulmonary reactions to exercise than their non-training counterparts, leading to greater central RPE scores. Since this central factor was being trained it would have been more subject to fatigue than the local component, thus leading to higher CRPE scores. Pardy and Bye (1985) noted increases in perceived respiratory effort, during fatiguing breathing exercise even though VE was held constant. These authors suggest that local muscle lactate, CaO_2 and/or the partial pressure of oxygen in the air may influence perceived respiratory effort. Since these variables were not measured their effect on CRPE in this study must remain unknown. Although fatigue is a plausible explanation for the increases in training CRPE scores it is debatable whether the training load was sufficently severe to cause diaphragmatic or respiratory muscular fatigue.

Scrutiny of the individual subject's data may provide a more logical explanation for the higher CRPE scores found in the training subjects. Although the mean aerobic power increased slightly between the perceptual tests, 50% of the subjects actually maintained or decreased VO_2 Max. and of the subjects who increased VO_2 Max. only two increased their values substantially (+10 and +7 $ml.kg.min^{-1}$), not surprisingly these were two of the most diligent subjects. These two subjects skewed the mean slightly, and thus the majority of the group may have had increased perceptual ratings due to their small or negative changes in fitness.

It should be noted that these results are in direct contrast with those training studies that have found decreases in RPE with training. The lack of decreases in RPE found in this study are probably related to the insignificant changes in VO_2 Max.

In summary, RPE was found to be associated with the relative cost of exercise, thus fit individuals perceived a given workload as being easier than their unfit counterparts. These results may have been biased by some factors such as the expectancy of improvement or habituation to the task. No signficant changes were seen as a result of training although possible explanations for the interactions found for time by group were discussed. Possible factors included associative strategies, fatigue, habituation and the training effects that had occurred previous to the testing protocol.

5.3 CORRELATIONAL ANALYSIS AND PREDICTION OF RPE

5.3.1 RELIABILITY

Test-retest data is shown in table 4.7. It is interesting to note that the training subjects were more consistent in their estimates of RPE than were their non-training counterparts. The trained subjects showed correlation coefficients (r's) of $r=0.709$ to 0.900, whereas the non-training group demonstrated r's of 0.531 to 0.864. These results compare favourably with the literature. Skinner et al. (1973) reported a test re-test coefficient of $r=0.80$ for a progressive test on a bicycle ergometer. Stamford (1976) also reported significant correlations for RPE on a progressive bicycle test ($r=0.76$, $p<0.01$), for 14 sedentary subjects.

It is interesting to note the higher correlations seen in the training subjects. Intuitively, lower correlations would have been expected in the training group since they underwent an intervention between the two tests. However, it is hard to escape the expectation that trained subjects are more aware of their physical responses to exercise, and can monitor these more accurately. An increased awareness of physical cues may be a result of increased association (discusssed above). An accurate awareness of perceptual cues would be desirable for optimum performance, and associative cognitive strategies have been found to characterise elite performance (Morgan, 1978). The evidence shown by Okwumbua et al. (1983) suggesting novices became more associative, gives support to the idea that exercise intensity (pace) can be learned by attending to bodily cues during exercise. Noble (1982) has suggested that perceived exertion could be used in the future for helping athletes learn pace-judgement for a variety of sports.

The non-training group may have been attempting to distract themselves from the discomfort of the exercise since it represented a highly stressful task (80 -90% $\dot{V}O_2$ max.). The effect of such a strategy would have meant that the non-training subjects were not accurately monitoring the cues resulting from the exercise. The training group on the other hand may have been more able to attend to their bodily cues due to the learning effect, their fitness levels and perhaps due to an increased pain tolerance. Wilmore (1968) has suggested that increases in performance are partly due to increases in pain tolerance. Thus one of the effects of training may have been an increased ability to read effort cues accurately. Increases in pain tolerance may have allowed the training subjects to attend to their physical reactions to exercise.

The face validity of the scale was supported by this study, since it was able to discriminate between groups of differing fitness. Thus groups working at higher percentages of their maximum capacity perceived the task as requiring more effort. Further support for the validity of the scale might arise from the observation that RPE's increased significantly as a result of an increase in treadmill stage (see Table 4.6). Skinner et al. (1973) and Stamford (1976) were concerned that the expectancy of increased work on progressive tests might bias perceived effort. However, data from these authors has confirmed the validity of the Borg scale using randomised workloads. Therefore it seems that the scale can be used to accurately reflect increases in workload intensity, even during progressive exercise.

Thus the results provide support for the Borg scale as a reliable and valid instrument. Further, it appears that training increases the reliability of the scale, perhaps as a result of increased association or body awareness.

The question of validity is an interesting one. Skinner et al. (1973) defined validity of RPE as the ability to discriminate workloads presented in a randomised order. Even though the RPE scale appeared to be 'valid' in Skinner et al.'s (1973) and Stamford's (1976) investigations, the level of subjectivity associated with the scale will always be a debatable point. Inter-individual variability in the perception of what is 'very, very light' (7) or 'very hard' (17) may affect the construct validity of the scale, and any correlations between RPE and more objective physiological measures. Figure 4.2a shows the means and standard deviations of the RPE scores for the two groups collapsed across both tests. Even though the reliability of the measures is high there is some variance about the mean for each group. Examination of Tables 4.4 and 4.5 indicates that the standard errors of the means (and standard deviations) for the three RPE measures are quite high. For example, the results for the first stage of mid-test revealed the following results: Training group, $M=7.92\pm1.78$; Non-training subjects, $M=11.0\pm1.77$.

Past studies have attempted to control for individual variations in perception of exertion by anchoring the top end of the scale (20) as equalling the most intense work ever performed. However, this may result in a ceiling effect on perceived effort (Morgan, 1981) which may lead individuals to 'pace' themselves up the scale (assuming the subjects know the length of the test).

5.4 CORRELATION AND PREDICTION OF RPE USING SELECTED PHYSIOLOGICAL VARIABLES

5.4.1 CORRELATIONAL ANALYSIS

It was mentioned in chapter 4 that the associations between the RPE and physiological variables appear very complex. Different relationships were seen as a function of stage, time and group (see Tables 4.8 to 4.11).

5.4.1.1 TRAINING DATA

The correlations obtained for the training group are shown in Tables 4.8 and 4.9. The data from the mid-test indicated that VE/VO_2 (positively) and VO_2 $l.min.^{-1}$ (negatively) were consistently associated with RPE in both stages of the test. ORPE did not correlate significantly with any physiological variables in the first stage and never correlated with VO_2 $l.min.^{-1}$. Minute ventilation appeared to correlate highly with all the RPE variables in the second stage of the test. The results from the second test indicated that VE/VO_2 and VE were highly associated with all the RPE variables in both stages of the test.

The negative correlation found between RPE and VO_2 $l.min^{-1}$ is contrary to all previously reported findings. Robertson (1982) cites positive correlations of 0.76 to 0.97 between VO_2 $l.min^{-1}$ and RPE. No significant correlations were seen when aerobic power was expressed in terms of body weight ($VO_2ml/kg.min^{-1}$), therefore body weight may have been a confounding factor during such weight-bearing activity. Nonetheless, a positive correlation between RPE and VO_2 $l.min^{-1}$ would be expected if weight was involved since, theoretically, heavier subjects would be doing more work. The results of the UANOVA analysis emphasised that the training subjects perceived the exercise as being easier when compared to non-trainers even though they were doing more work. The abnormal relationship of RPE and VO_2 $l.min^{-1}$ may therefore be an interaction of fitness level and body weight even within the training group.

High levels of association between VE/VO_2, VE $l.min^{-1}$ and RPE have been reported in the literature. Morgan and Pollock (1977) for example found a correlation coefficient between VE and undifferentiated RPE of 0.52 ($p<0.01$) during submaximal treadmill running (12 mph., 0% grade) with elite and college level runners. Morgan et al. (1976) noted parallel increases in VE $l.min^{-1}$ and RPE as result of hypnotic suggestions. Noble et al. (1973) found that minute ventilation accounted for the greatest amount of variance in RPE at 5 and 15 minutes of exercise during a 30 minute work bout. Edwards et al. (1972) showed pearson correlation coefficients of 0.939 and 0.896 respectively between RPE and VE $l.min.^{-1}$ during continuous and discontinuous work. Evidence against VE $l.min^{-1}$ as an input to RPE has been shown by Cafarelli and Noble (1976) and Stamford and Noble (1976), (see section 2.2.2.3).

VE/VO_2 has also been suggested as a dominant input to RPE (Young et al., 1982; Pandolf, 1984); however, this remains a variable that has not been researched extensively in the RPE literature. Nevertheless VE/VO_2 is used as the best indicator of aerobic and anaerobic thresholds (A. Quinney, personal communication 1986), and may therefore be a potent physiological cue for the perception of increases in work output. Further evidence supporting VE/VO_2 as a cue for RPE is the fact that both variables have been shown to increase exponentially in response to increased workloads (see Astrand and Rodahl, 1977 and Borg, 1982).

A possible mechanism for the input of VE $l.min^{-1}$ cues to RPE has been explained in section 2.2.2.3.. This theory revolves around the concept that VE $l.min^{-1}$ begins to parallel RPE at approximately 50% VO_2 Max. (Robertson, 1982). VE/VO_2 would also be expected to parallel VE since the former is calculated using the latter. Increases in VE $l.min.^{-1}$ parallel the increased metabolic cost of exercise and may mediate the potential effects of VO_2 on RPE. However, as the intensity of exercise increases above the anaerobic threshold (Skinner and McLelland, 1980) (>65-90% VO_2 max.) the amount of lactate increases sharply. VE $l.min^{-1}$ therefore increases faster than VO_2 in order to expel the CO_2 produced by the bicarbonate buffering system. This exponential rise in VE $l.min^{-1}$ is reflected in the VE/VO_2 ratio since VO_2 increases linearly. These two ventilatory cues offer support for Noble et al.'s (1973) hypothesis that physiological processes are probably indirectly monitored through their directly perceivable externalisations. VE $l.min^{-1}$ and VE/VO_2 may therefore be correlated with CRPE by virtue of the perception of respiratory drive. The high correlation of LRPE and these two physiological variables might be explained by the possible sensations of the anaerobic metabolites via free nerve endings (Mihevic, 1981). LRPE and CRPE may thus be highly correlated at these higher levels of exercise by their common association with anaerobic processes.

A reason for the between-test differences seen in the correlations with VE $l.min^{-1}$ may have been that the training subjects became more associative as a result of training; however, this idea remains speculative. It is interesting to note anecdotal reports that individuals who exercise often associate windedness or hyperventilation with being fatigued (A. Quinney, personal communication 1986). Experience of such physiological cues may strengthen the salience of ventilatory variables as inputs to the effort sense. MacDougall and Sale (1981) have mentioned that experienced athletes often use the perception of increased ventilatory drive as an indicator of anaerobic threshold.

Examination of Figure 4.3c shows the group by stage interaction found for VE/VO_2. The non-training group showed a highly increased VE/VO_2 ratio during the second stage of the tests. This interaction may help to explain the differences between the training and non-training group's perceived exertion during the higher exercise intensities.

Overall RPE would be expected to correlate highly with CRPE and LRPE since it is a combination of both measures; however, ORPE did not correlate with the physiological measures as highly as LRPE and CRPE. An analysis of the inter-correlations between the RPE measures in the training group shows that the coefficients (r's) range from r=0.985 to 0.899. These seem very high, but indicate that the three RPE constructs may be measuring slightly different factors. The different levels of association between CRPE, LRPE and ORPE and the physiological measures also indicate this.

5.4.1.2 NON-TRAINING GROUP DATA

Analysis of the non-training group data indicates less consistent associations between the perceptual and physiological variables. During the first test the only two variables to significantly correlate are VO_2 ml/kg.min^{-1} and LRPE ($p<0.01$). In the first stage of the second test (post-test) %VO_2 Max. and CRPE ($p<0.05$) are directly related. VO_2 l.min^{-1} was negatively correlated with LRPE ($p<0.01$) and ORPE ($p<0.05$). %VO_2 Max. was the only physiological variable significantly correlated with CRPE ($p<0.01$) and LRPE ($p<0.05$) during the second stage of the second test.

The different physiological variables found at each stage concur with the training group's results. However, there appears to be no coherent explanation for most of the correlations seen for the non-training group. The less consistent correlations seen with these central (aerobic) cues may reflect anecdotal reports that local factors may limit exercise in unfit participants, and may therefore be more salient cues (A. Quinney, Personal communication 1986).

The factors underlying the negative correlation of VO_2 l.min^{-1} with RPE may be similar to those suggested for the training group. Neverthless, it is interesting to note that both groups had a similar association with this variable, but it must be kept in mind that these variables were associated with RPE in different tests (training, mid-test; non-training, post-test).

A positive association with VO_2 ml/kg.min^{-1} might be expected since RPE would be predicted to rise as the oxygen cost of the exercise relative to bodyweight increases.

The correlations of %VO_2 Max. also agree with the results of the analysis involving the data of both groups analysed together, which was discussed earlier (see section 5.2.1).

The relationships between aerobic power and perceived exertion in the present study remain unclear, especially the differential effects of absolute and relative values. However, the data partly supports some of the arguments cited for and against aerobic power as a cue for RPE which were discussed in section 2.2.2.2.; thus, %VO_2 Max. may be a more potent cue than VO_2 $l.min^{-1}$ or $ml./kg.min.^{-1}$.

The inconsistency of the non-training data when compared to the training group's results is an interesting point. This difference might be explained by the lack of opportunity for the non-training group to associate with their bodily sensations resulting from exercise. A further explanation might involve the possible effect of dissociative strategies found in exercise naiive subjects (Okwumbua, 1983), which would be expected to result in inaccurate perceptions of bodily states since attention is being turned away from these intentionally.

The less uniform results of the non-training group may also be explained statistically. The small sample size (n=8) and the fact that correlations were ascertained within each stage of the test which would increase the homogeneity of the data may have resulted in these findings. However, the variance in the data is quite large (see Table 4.5), and this and the small sample size may have exaggerated the correlations for some variables and reduced these for others (Hopkins and Glass, 1978; Wilmore, 1968).

The weaker relationships among the non-training group's three different RPE measures might also affect the relationships between a given physiological measure and the individual components of the differentiated RPE model.

5.4.1.3 COMPARISON OF GROUPS AND SUMMARY

To summarise this section the training and non-training groups demonstrated high levels of association between the RPE measures and some physiological variables. The most consistently correlated variables for the training group were VE/VO_2, and VE $l.min^{-1}$. There was less consistency in the degree of association between perceptual and physiological data for the non-training group, although %VO_2 Max. was the most consistent correlate of RPE during the second test.

Due to the abscence of control and non-training groups and sparse use of the differentiated model in past studies on training and RPE, this data cannot be compared to any other studies. The uniqueness of the present correlational study also prevents a parallel analysis with other investigations.

The differences found between the groups were discussed in terms of the possible associative learning effect as a result of training. These correlations should be interpreted with some care, since the small sample sizes of the groups (n=12, training; n=8, non-training subjects) and variability within each group may have exaggerated some of the coefficients. The different group sizes may also partially account for the differences in the magnitude of the correlations reported for both groups.

In summary, RPE is a complex integration of physiological and psychological factors that should be expected to vary at least as widely as other complex perceptions (see chapter 2). The variability in results may arise from the influence of other variables such as personality, task aversion, perceptual style, or other factors arising from the subject's life history. Accounting for such factors, and the innumerable interactions among them, was beyond the scope of this study.

5.5 REGRESSION ANALYSIS

Since the regression analysis was completed on a 'collapsed' sample (n=20) it revealed portions of the variance in ORPE explained by both groups. The increased variance in the data caused by the combination of the two groups would also change the levels of association between some variables.

The regression analysis did not reveal any physiological predictors of ORPE in the first test apart from the distinction between the training and non-training groups. This data simply reflected the results discussed in earlier sections.

The analysis on the second test resulted in different findings. VE/VO_2 and $\%VO_2$ Max. were found to be the best predictors of ORPE in the first stage. VE/VO_2 alone was the best predictor in the second stage of this test (see section 4.5). The difference in predictors seen between tests may again reflect the tentative hypothesis that the training group became more associative over time.

The increased salience of VE/VO_2 as a function of test stage might simply reflect the increased ventilatory drive caused by working at higher percentages of VO_2 Max. The inclusion of $\%VO_2$ max. in the first stage of the second test mirrors the high correlations found between these two variables ($p<0.004$, see Appendix G). The differences in variance between the collapsed data and the individual groups would explain the different levels of association seen between the correlational and regression analyses.

To the author's knowledge two multiple regression analyses have been conducted using physiological data as a predictor of RPE. The data found in the present study support some of the earlier findings. Noble et al. (1973) used a procedure that resulted in 8 variables accounting for the variance in undifferentiated RPE. These variables were VE $l.min^{-1}$, VO_2 $l.min^{-1}$, respiratory quotient (RQ), respiratory rate (RR), heart rate (HR), VCO_2 $l.min.^{-1}$, skin and rectal temperature. The salience of these variables changed according to exercise duration; however, VE $l.min^{-1}$ was the most potent predictor of RPE at 5 and 15 min of exercise. At 30 minutes of exercise RR and then VE were the most salient cues. These cues were supported as potential inputs to RPE since they are readily perceived. It should be noted that these data were generated using bicycle exercise and may not be generalisable to other exercise modes (Noble et al., 1973). VE/VO_2 was not measured in this investigation. Since the VE/VO_2 ratio is computed using VE $l.min^{-1}$ it is not surprising to find a strong relationship between the two. VO_2 has been shown to increase linearly with exercise intensity (Astrand and Rodahl, 1977) thus VE/VO_2 represents a linear transformation of VE $l.min.^{-1}$. VE/VO_2 should therefore closely reflect the increase in VE $l.min^{-1}$, and be a possible predictor of RPE.

Pandolf et al. (1984) provide evidence to support the previous contention. These authors conducted a multiple regression study on differentiated RPE and selected physiological measures using cycling and arm cranking exercise. The results indicated that VE/VO_2 made the most contribution to the total accountable variance in overall RPE during absolute and relative cycle exercise. The data from the present study therefore support both Pandolf et al.'s

(1984) and Young et al.'s (1982) findings that VE/VO_2 is a salient cue for RPE (section 2.2.2.4)

The differences in predictor variables seen between the present study and the two earlier works may be due to the exercise modes, protocols or subject populations and numbers used. Pandolf et al. (1984) used 9 male subjects who performed 60 mins. cycle exercise at 60% VO_2 Max., and 6 minutes work at 30 watts. Noble et al. (1973) used 6 highly fit students (VO_2 Max. > 51 ml/kg.min.$^{-1}$). The protocol involved cycling for three trials of 30 mins. at 48, 60 and 68% VO_2 max. Thus it is clear that the nature of the sample, exercise duration (3.5 minutes), intensity (>70% VO_2 max.) and task (treadmill running) of the present study represent considerably different conditions to earlier studies.

Despite differences between the design of the present study and earlier studies there is considerable agreement and strong support for VE/VO_2 as as input to overall RPE. However, further analysis to explain the variance in central or local RPE may result in different clusters of physiological cues. This remains a problem for future research.

6. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

The purposes of this study were threefold. Firstly to examine any differences in perceived exertion between groups of different fitness levels during an absolute exercise task. A second objective was to assess the stability of RPE ratings using the Borg scale (1970) over time. Finally, the relationship between RPE and selected physiological methods was assessed using correlational and multiple regression analyses.

Subjects consisted of a training group (n=12) and a non-training group (n=8). The training involved the final 3 months of a six month jogging program in which training volume was systematically increased over time. The non-training group was not involved in any regular physical activity. The subjects were tested twice with 3 months between the tests. The Borg (1970) RPE scale utilising the differentiated model (central, local and overall RPE) was employed as the measure of perceived exertion. The RPE and physiological measures were taken at 2.5 and 4.5 minutes of exercise of a progressive treadmill test (5.5 and 6.5 mph. respectively).

6.2 CONCLUSIONS

On the basis of the data generated from this investigation the following conclusions are drawn.

1. It appears that use of the Borg scale can discriminate between groups differing in fitness, exercising on an absolute treadmill workload. Fitter subjects perceive an absolute workload as requiring less effort than their less fit counterparts. Therefore RPE seems to be related to relative rather than absolute levels of work. This could have implications for using RPE as a method of prescribing exercise intensity.
2. The Borg scale appears to be a reliable instrument across a 3 month time period; however, the training subjects seem to be more consistent in giving RPE ratings than do controls.

The reliability and validity of RPE may therefore be enhanced by a learning effect mediated through training. Learning to reproduce RPE may be a function of increased body awareness facilitated by increased exercise experience.

The face validity of the Borg scale also seems to be supported, since more stressful relative workloads were perceived as requiring more effort.

3. The physiological cues that showed the most consistent relationships with RPE were VE $l.min^{-1}$ and VE/VO_2. Both of these cues may be directly perceivable through the process of ventilation. These findings are supported by the literature. The more consistent findings were produced by the training group which may also arise from the learning effect referred to in number 2 above.

4. The use of the differentiated model of RPE (CRPE, LRPE, ORPE) is supported by the present study. The separate portions of the differentiated model appeared to be measuring different constructs. This was supported by inter-correlations deviating from unity and the different physiological measures associated with each RPE variable.

5. Although some consistent associations were found between the physiological and perceptual variables, some inconsistencies were found between groups, tests and stages within tests. These inconsistencies might arise from the variability in the data, the small sample sizes used, the unstable nature of perceptions or other unknown sources.

6. Because of the non-random selection and unequal size of the groups, as well as the differences in perceptual judgement in RPE on the first test, generalising to other populations is not justifiable. In addition, differences in methodology make the comparison of results from this study with those from other studies difficult to justify.

7. As a final summary perceived exertion appears to be a complex construct involving a complex interplay of physiological and psychological factors.

6.3 RECOMMENDATIONS

6.3.1 REPLICATION OF STUDIES

Due to the large variability in experimental designs, the past investigations on fitness, training and RPE have resulted in equivocal findings. Further controlled, replicative studies should be initiated to clarify this particular area of research. These studies should also be 'blind' in order to reduce the possible level of experimenter bias.

6.3.2 COGNITIVE STRATEGIES

The results from this study and past literature tentatively suggest that training may lead to changes in perceptual thresholds (pain tolerance) or associative cognitive strategies. Further controlled longitudinal investigations should be performed to assess these possible parameters.

6.3.3 TRAINING ADHERENCE

The total duration of this training study was 6 months. The results showed that the ability to maintain a given exercise schedule decreased after 3 months. Further insight on this point will be presented in later analysis of the data.

The use of heart rate monitors may be a useful adjunct to the practice of pulse-taking as a method of teaching exercise intensity to novice subjects. A more interactive training method (e.g., fitness classes) may also be more suitable to maintain long-term adherence.

Field studies on the application of RPE as a method of prescribing exercise may be an interesting area for further research.

6.3.4 ENHANCED RESEARCH DESIGN

Any future replications of this study should attempt to overcome the weaknesses in the present research design. For example, a larger number of subjects should be <u>randomly</u>

assigned to training and control groups from a common population. Furthermore, a relaxation or placebo group should be used to control for expectancy effects.

Secondly, the design should measure the effects of the greater increases in fitness often seen in the earlier stages of a training program. This may involve the use of a less severe testing protocol than that utilised in the present study.

Finally, further physiological variables such as sweating, heart rate or core temperature could be measured. A greater number of variables may help account for a larger proportion of the variance in perceived exertion (Morgan, 1981).

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APPENDICES

APPENDIX A

INFORMED CONSENT FORMS

STUDY OF SEDENTARY WOMEN

I do consent to take part in a 3 month study designed to investigate the perceived exertion, and the maximal oxygen uptake of sedentary females. I understand that this study will require that I:

1. Attend an orientation session to the test protocol.
2. Take part in two maximum oxygen uptake tests on a treadmill three months apart.
3. Complete the Clinical Analysis Questionnaire (a measure of personality) twice.
4. Complete a profile of mood states (measuring mood), at each test.

I understand that on completion of the study (ie. all of the information above), I will receive the sum of $25-00 Can.

I understand that the purpose of the treadmill test is to measure the maximum amount of oxygen which I can utilise while running. I will be given instructions on running on the treadmill and breathing through the collection system and be allowed to practise. A technician will tape two electrodes to my chest to monitor my heart rate. During the test I will run at two speeds, first at 5.5 mph (a warm up) for two minutes, then at 6.5 mph for a further two minutes. The treadmill speed will remain at 6.5 mph, but the slope of the treadmill will increase 2° every two minutes. The test will be terminated when I grasp the bar to indicate that I wish the test to be terminated, <u>or</u> when the investigator perceives that I am at VO_2 max. (maximum oxygen uptake) or suffering from undue stress. I realise that I should keep running until I feel that I am unable to maintain the pace set by the treadmill.

Although I will be undergoing exercise to the point of temporary exhaustión, I realise that there is very little risk involved if you are a normal healthy individual.

I understand that I may discontinue any of the physical tests should I feel uncomfortable, and that the investigators are qualified registered fitness appraisers and will monitor me fully throughout the tests. I understand the risks involved in the test procedures and hereby waive any responsibility of the investigators or university should any injury or mishap occur.

I understand that all the information gained during the study will be treated with the utmost confidence by the investigators and that no part shall be published involving my name.

Signed Participant

Witness/Investigator

This day of

Day/Month/Year.

OVERVIEW OF POSITIVE AND NEGATIVE IMPLICATIONS OF PROGRESSIVE RUNNING AND INFORMED CONSENT

Further to our discussion of the possible negative implications of long distance running, we would like to provide you with current information on both positive and negative effects. After reading this document, we require you to sign a statement of informed consent. Additionally, since we closely monitor your training, any negative effects of running will be more likely identified than if you were not in this study. It should be emphasised that there is no guarantee against health hazards.

If you or the researchers identify any health problems, you will be referred to an appropriate professional. Also, if you desire to withdraw from the study for this reason, you will be given a full refund of your deposit.

The following list provides a summary of the effects of training according to current research literature and speculations. Should you require additional information regarding these effects you are invited to contact any of the principal investigators (Garry Wheeler, Dept. of Physical Ed.; Dr. W.F. Epling, Dept. of Psychology; Dr. M. Singh, Dept. of Physical Ed.; Dr. D.C. Cumming, Obst. and Gyn., U of A Hospital; Dr. W.D. Pierce, Dept. Sociology).

NEGATIVE EFFECTS

-sports injuries (i.e., shin splints)

-excacerbation of present/hidden coronary problems

-hormonal changes including amenorrhea in women and low testosterone levels on men.

-activity anorexia in rats and personality similarities between high mileage runners and anorectics

-addicition to running

POSITIVE EFFECTS

-cardiovascular improvements

-improved fitness

- increased muscle tone
- reduction in body fat
- improved self-esteem
- improved body-image
- interpersonal gains/social relationships

I HAVE READ THIS DOCUMENT AND UNDERSTAND THE POSSIBLE POSITIVE AND NEGATIVE EFFECTS OF A PROGRESSIVE ENDURANCE RUNNING PROGRAMME

NAME ....

WITNESS...

DATE ....

SIX MONTH TRAINING AND

DIET STUDY

Form of Informed Consent

Training Groups

I ______________________________ do consent to be part of a 6 month training program of progressive endurance running and of dietary intake. I understand that the program will consist of:

(i) A pre-test involving a submaximal evaluation of maximum oxygen uptake on a bicycle ergometer.

(ii) A pre-program assessment of maximum oxygen uptake on the treadmill and assessment of percent body fat by skinfolds and underwater weighing. A respiratory parameter will be assessed at the University of Alberta Pulmonary Laboratory, and all participants will complete the Clinical Analysis Questionnaire to measure personality and the Eating Attitudes Test to measure attitudes toward food and eating.

(iii) A pre-program instructional session on the recording of dietary intake.

(iv) A pre-program orientation session on the principles of aerobic training, target heart rate, anaerobic threshold and heart rate recording.

(v) A pre-program blood sample of approximately 20 ml. by venupuncture and taken by a qualified technician.

(vi) Recording diet for 3 days in a diet diary on Thursday, Friday and Saturday during alternate weeks.

(vii) A six month endurance running program requiring participation in 3 weekly runs during month 1 and progressing to 6 weekly runs during month 6.

(viii) A post test procedure involving maximal oxygen uptake assessment, percent body fat by underwater weighing and skinfolds and a repeat of the Eating Attitudes test and clinical analysis questionnaire and measurement of respiratory parameters at the Pulmonary Lab. at the University of Alberta hospital.

I also understand that a hundred dollar deposit will be required at the beginning of the study, of which a fifty dollar minimum is refundable. I understand that any monies retained will be used only for research purposes associated with the study.

I understand that if I drop out for reasons other than those considered mitigating circumstances by the investigatory committee that I shall lose my deposit. In the event of family problems or injury of a chronic nature I understand I shall receive my money back on a pro-rated basis up to 50 dollars and receive the other fifty dollars back in full.

. . . / 2

I understand that I may discontinue any of the physical pre-tests should I feel uncomfortable and that the investigators are qualified registered or certified fitness appraisers and will monitor me fully throughout all tests. I understand the risks involved in the test procedures and hereby waive any responsibility of the investigators or university should any injury or mishap occur. I understand that I should be cleared medically to participate in the study and provide a written physicians statement to vertify my physical readiness.

I understand that all information gained during the study will be treated with the utmost confidence by the investigators and that no part shall be published involving my name.

Signed ______________________________ Participant

______________________________ Witness/Investigator

This day of ______ ______________

Day Month Year

APPENDIX B

EQUIPMENT AND CALIBRATION PROCEDURES FOR THE MAXIMAL, SUB-MAXIMAL EXERCISE TESTS, AND ESTIMATIONS OF BODY FAT

1. MAXIMAL TREADMILL TESTS

All the respiratory parameters were measured by a Beckman Metabolic Measurement Cart (Sensormedics Corporation, 1630 South State College Blvd., Anaheim, CA 92806, U.S.A.).

The measurement cart was calibrated following the procedures outlined in Section Three of the manufacturers operating instructions manual. The operations described in sections 3.1 to 3.10 were performed with the exception of sections 3.6.2, 3.7.3 and 3.7.4. The metabolic cart was operated using a single card exercise metabolic program (EX 675511).

-Expired gas was collected using a Rudolph three-way valve, (Hans Rudolph, Inc., Kansas City, U.S.A.). A headpiece was used to hold the valve in place .

-Heart rate was monitored by a cardiotachometer (Cardionics, A.B., Stockholm, Sweden) connected to two 3-M Red Dot Ag/AgCl electrodes (#2259), (3M Canada Inc., London, Ontario). The electrodes were placed on the sternum and at approximately the 5th. left intercostal space at the mid axillary line.

2. SUB-MAXIMAL CYCLE ERGOMETER TESTS

Two Quinton 870 electrically braked cycle ergometers (Quinton Instruments, Scarborough, Ontario) were used for the submaximal screeening tests. The ergometers had been dynamically calibrated by the manufacturers, during the eight month period preceding the tests. Heart rates were monitored by PE-2000 Sport Testers (Polar Electro, Finland).

3. BODY FAT MEASUREMENTS.

1. Pre-screening procedures: Harpenden Skinfold Calipers were used for the estimation of body fat using the sum of four skinfolds (Government of Canada, 1984).

2. Experimental Procedures: Body fat was estimated using the densitometry body density method; Calibration and weighing procedures were as follows:

1. Subject was weighed in a bathing suit on a balance beam scale.
2. The chart recorder was zeroed and the chart span set to 75 with the weight belt set on the chair.
3. The subject was asked to sit on the chair and expel all air from the bathing suit and from their hair.
4. Vital capacity was measured three times using a vitalometer. The average of the greatest two measures was taken as vital capacity. Vital capacity was measured in the seated position.
5. The subject was then instructed to submerge slowly while holding a full breath (ie. full inhalation).
6. The subject was instructed to hold a full breath until signalled to come up for a breath by means of a sharp tap on the side of the tank.
7. Body density was measured three times and then the load cell recalibrated and a further measure taken to control for drift. In the event that drift had occurred then the subject was reweighed following recalibration.
8. The mean of the two lowest measures was taken and substituted into the equation (see next page).

Body weight was determined by a balance beam medical scale (Continental Scale Corporation, Bridgeview, Ill., U.S.A.). The scale was calibrated against a known weight, and adjusted if necessary.

ESTIMATE OF BODY COMPOSITION

Name ______________________ M __/ F __/ Date __________ Water Temp. ______

Measurements:

1. Dry Weight ______ (lbs.)
2. Vital capacity __________ l
3. Residual Vol. ____(l)_____ (cu.in.)
4. VGI ____7.01____ (cu. in.)
5. Chart reading __________
6. Underwater Weight __________ (lbs.)
7. Weight belt __________ (lbs.)
8. Unit range on recorder __________
9. Water density __________

Calculations:

6. Underwater Weight = $\left[\dfrac{\text{Weight belt x chart reading}}{\text{Unit range on recorder}}\right]$ - wt. belt

Underwater weight = $\left[\dfrac{\qquad\qquad}{\qquad}\right]$ -

Underwater weight = __________

10. TBA = ________VC (cu. in.) + ________RV (cu.in.) + 7.01 VGI (cu.in.) =

________TBA (cu.in.) x .0362 = ______________ TBA

11. True Underwater Wt.= __________ Underwater wt.(6) + __________ TBA(10)

= __________ lbs.

12. Body Volume = __________ dry wt.(1) - __________ true underwater (11) = __________

13. Body Density = __________ dry wt.(1)/ ________ Body Vol (12) x __________ water density(9) = __________.

14. % Fat = [(4.570 / Body density) - 4.142] x 100 = __________.

15. Lbs. fat = __________ % fat x __________ dry wt. = __________.

16. Lbs. fat free = __________ dry wt. - __________ lbs. fat = __________.

NOTES:

a) TBA = Total body air
b) RV = 30% of VC for men; 25% of VC for women
c) To convert l to cu.in., multiply by 61.02.

APPENDIX C

INSTRUCTIONS FOR RPE

At various times during the exercise test, I will be asking you to give me a rating of the 'physical exertion' or physical fatigue that you are experiencing at that particular moment.

I would like you to point to an appropriate number on this scale in front of you. As you will see the scale ranges from 6 - 20; 6 is the lightest work, 20 should be associated with the heaviest work that you have ever performed. (However, it is possible to perceive effort more stressful than 20). There are descriptive labels at the odd numbers to give you some guidance as to their meanings.

I would like you to give me three (3) ratings:

<u>1. CENTRAL:</u> Focus your attention specifically on your heart rate and your breathing and estimate the exertion or effort you are experiencing in your heart-lung or cardio-pulmonary systems.

<u>2. LOCAL:</u> Now shift your attention specifically to focus on the feelings of strain that you are experiencing in the muscles and joints of your legs.

<u>3. OVERALL:</u> Now shift from a specific focus to a very general, broad focus - what degree of exertion do you feel overall as you work. You may give the local and central feelings any weightings you deem appropriate.

Please try to estimate your exertion and/or fatigue as objectively as possible. Try not to underestimate it or overestimate it. Aim to estimate it as accurately as possible.

Adapted from Morgan (1981).

APPENDIX D

TRAINING SCHEDULE

Training mileage

Month	(1)				(2)				(3)			
week	1	2	3	4	1	2	3	4	1	2	3	4
(1)		1.5	1.5	2.0	2.0	2.5	2.5	2.5	2.5	3.0	3.0	3.5
(2)	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	2.5	2.5	3.0	3.0
(3)	1.0	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.5
(4)								2.5	3.0	2.5	3.0	3.0
TOTAL				(5.5)				(10)				(13)

(Max. 2 miles/session) (Max. 3 miles/session) (Max 3½ miles/session)

Month	(4)				(5)				(6)			
week	1	2	3	4	1	2	3	4	1	2	3	4
(1)	4.0	4.0	4.5	4.0	4.0	4.0	4.5	4.0	4[illegible]	[illegible].5	5.0	5.0
(2)	3.5	4.0	4.0	4.0	4.0	4.5	4.5	4.0	4.5	4.5	4.5	5.0
(3)	4.0	4.0	4.5	4.0	4.0	4.5	4.5	4.0	4.5	5.0	5.0	5.0
(4)	3.5	4.0	4.0	4.0	4.0	4.5	4.5	4.0	4.5	4.5	4.5	5.0
(5)				4.0	4.0	4.0	4.5	4.0	4.5	4.5	5.0	5.0
(6)								4.0	4.0	4.0	4.5	5.0
TOTAL				(20)				(24)				(30)

(Max. 4.5 miles/sess.) (Max. 5 mi/sess.) (Max. 6 miles/session)

TRAINING PROGRAM FOR THE TRAINING GROUPS

APPENDIX E

UANOVA SUMMARY TABLE, VO_2, BODY WEIGHT, BODY FAT

THE VARIABLES IN THE FOLLOWING APPENDICES ARE CODED AS FOLLOWS:

CRPE, CENTRAL PERCEIVED EXERTION

LRPE, LOCAL PERCEIVED EXERTION

ORPE, OVERALL PERCEIVED EXERTION

VE, MINUTE VENTILATION (l/min.)

PVO, PERCENTAGE OF VO2 MAX.

VOL, VO2 l/min.

OKG, VO2 ml/kg./min.

VEO, VE/VO2 RATIO

VCO, VCO2 l/min.

11, stage 1, test 1

12, stage 2, test 1

21, stage 1, test 2

22, stage 2, test 2

BF, BODY FAT

BW, BODY WEIGHT

VO1, VO2 MAX.

SS, SUM OF SQUARES
MS, MEAN SQUARE - E, ERROR TERM; H, HYPOTHESIS TERM
DF, DEGREES OF FREEDOM

SUMMARY STATISTICS FOR TRAINING GROUP (n=12) AND NON-TRAINING GROUP (n=8).

VARIABLE	MEAN	S.E. MEAN	STD DEV	VALID N	LABEL
VO1	35.900	1.274	4.226	11	vo2 test 1
VO2	43.808	1.289	4.467	12	vo2 test 2
VO3	45.283	1.344	4.656	12	vo2 test 3
BW1	60.133	1.432	4.962	12	body weight test 1
BW2	60.225	1.382	4.788	12	body weight test 2
BW3	60.208	1.623	5.621	12	body weight test 3
BF1	26.727	2.139	7.095	11	percent body fat test 1
BF2	24.767	1.033	3.577	12	percent body fat test 2
BF3	24.875	1.215	4.208	12	percent body fat test 3

VARIABLE	MEAN	S.E. MEAN	STD DEV	VALID N	LABEL
VO1	35.500	1.124	2.513	5	vo2 test 1
VO2	37.537	1.663	4.702	8	vo2 test 2
VO3	36.650	1.230	3.479	8	vo2 test 3
BW1	55.120	1.064	2.378	5	body weight test 1
BW2	56.450	1.384	3.916	8	body weight test 2
BW3	56.500	1.436	4.062	8	body weight test 3
BF1	26.400	1.210	2.964	6	percent body fat test 1
BF2	26.214	1.690	4.470	7	percent body fat test 2
BF3	26.512	1.193	3.376	8	percent body fat test 3

SUMMARY UANOVA TABLE FOR MAXIMAL OXYGEN CONSUMPTION (VO), BODY WEIGHT (BW) AND BODY FAT (BF)

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR VO

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP	343.30	623.63	343.30	34.65	9.91	1.0	18.0	0.0056
UNIV	CASES(GRP)	* 623.63	277.67	34.65	8.68	3.99	18.0	32.0	0.0003
UNIV	GRAND MEAN	89200.45	277.67	89200.45	8.68	10279.82	1.0	32.0	0.0
	GREENHOUSE-GEISER ADJ:	EPSILON	0.93	89200.45	8.68	10279.82	0.9	29.7	0.0
UNIV	TIME	450.44	277.67	225.22	8.68	25.96	2.0	32.0	0.0
	GREENHOUSE-GEISER ADJ	EPSILON	0.93	225.22	8.68	25.96	1.9	29.7	0.0
UNIV	GRP*TIME	139.27	277.67	69.64	8.68	8.03	2.0	32.0	0.0015
	GREENHOUSE-GEISER ADJ	EPSILON	0.93	69.64	8.68	8.03	1.9	29.7	0.0020
UNIV	CASES(GRP)	* 623.63	277.67	34.65	8.68	3.99	18.0	32.0	0.0003
UNIV	TIME*CASES(GRP)	* 277.67	****	8.68	****	****	32.0	****	****

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR BF

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP	8.78	740.33	8.78	41.13	0.21	1.0	18.0	0.6495
UNIV	CASES(GRP)	* 740.33	340.16	41.13	10.63	3.87	18.0	32.0	0.0004
UNIV	GRAND MEAN	37064.58	340.16	37064.58	10.63	3486.83	1.0	32.0	0.0
	GREENHOUSE-GEISER ADJ	EPSILON	0.62	37064.58	10.63	3486.83	0.6	19.9	0.0
UNIV	TIME	13.30	340.16	6.65	10.63	0.63	2.0	32.0	0.5414
	GREENHOUSE-GEISER ADJ	EPSILON	0.62	6.65	10.63	0.63	1.2	19.9	0.4718
UNIV	GRP*TIME	15.48	340.16	7.74	10.63	0.73	2.0	32.0	0.4907
	GREENHOUSE-GEISER ADJ	EPSILON	0.62	7.74	10.63	0.73	1.2	19.9	0.4327
UNIV	CASES(GRP)	* 740.33	340.16	41.13	10.63	3.87	18.0	32.0	0.0004
UNIV	TIME*CASES(GRP)	* 340.16	****	10.63	****	****	32.0	****	****

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR BW

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP	216.10	1052.03	216.10	58.45	3.70	1.0	18.0	0.0705
UNIV	CASES(GRP)	* 1052.03	63.87	58.45	1.94	30.20	18.0	33.0	0.0
UNIV	GRAND MEAN	196416.07	63.87	196416.08	1.94	101478.75	1.0	33.0	0.0
	GREENHOUSE-GEISER ADJ	EPSILON	0.80	196416.08	1.94	101478.75	0.8	26.4	0.0
UNIV	TIME	2.88	63.87	1.44	1.94	0.74	2.0	33.0	0.4833
	GREENHOUSE-GEISER ADJ	EPSILON	0.80	1.44	1.94	0.74	1.6	26.4	0.4567
UNIV	GRP*TIME	4.18	63.87	2.09	1.94	1.08	2.0	33.0	0.3510
	GREENHOUSE-GEISER ADJ	EPSILON	0.80	2.09	1.94	1.08	1.6	26.4	0.3405
UNIV	CASES(GRP)	* 1052.03	63.87	58.45	1.94	30.20	18.0	33.0	0.0
UNIV	TIME*CASES(GRP)	* 63.87	****	1.94	****	****	33.0	****	****

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND. IF SO, RESIDUAL IS USED

APPENDIX F

UANOVA SUMMARY TABLES, PERCEPTUAL AND PHYSIOLOGICAL DATA

SUMMARY STATISTICS FOR TRAINING GROUP (n=12) AND NON-TRAINING GROUP (n=8)

NUMBER OF VALID OBSERVATIONS (LISTWISE) = 12.00

VARIABLE	MEAN	S.E. MEAN	STD DEV	VALID N	LABEL
CRPE11	7.917	.514	1.782	12	central rpe stage 1, test 1
LRPE11	8.167	.548	1.899	12	local rpe stage 1, test 1
ORPE11	8.333	.512	1.775	12	overall rpe stage 1, test 1
VE11	56.742	3.193	11.060	12	ve stage 1, test 1
PVO11	70.208	1.841	6.379	12	percent vo2 max stage 1, test 1
VOL11	1.842	.046	.158	12	vo2 l min stage 1, test 1
OKG11	30.625	.828	2.867	12	vo2 ml kg min stage 1, test 1
VEO11	31.042	1.897	6.571	12	ve/vo2 stage 1, test 1
VCO11	1.845	.072	.250	12	vco2 stage 1, test 1
CRPE12	10.333	.711	2.462	12	central rpe stage 2, test 1
LRPE12	10.250	.719	2.491	12	local rpe stage 2, test 1
ORPE12	10.583	.743	2.575	12	overall rpe stage 2, test 1
VE12	68.400	3.538	12.256	12	ve stage 2, test 1
PVO12	80.758	2.097	7.263	12	percent vo2 max stage 2, test 1
VOL12	2.110	.036	.124	12	vo2 l min stage 2, test 1
OKG12	35.150	.665	2.303	12	vo2 ml kg min stage 2, test 1
VEO12	32.592	1.858	6.436	12	ve/vo2 stage 2, test 1
VCO12	2.257	.067	.232	12	vco2 stage 2, test 1
CRPE21	8.583	.514	1.782	12	central rpe stage 1, test 2
LRPE21	9.083	.679	2.353	12	local rpe stage 1, test 2
ORPE21	9.083	.633	2.193	12	overall rpe stage 1, test 2
VE21	56.142	2.294	7.948	12	ve stage 1, test 2
PVO21	69.700	1.674	5.799	12	percent vo2 max stage 1, test 2
VOL21	1.878	.039	.136	12	vo2 l min stage 1, test 2
OKG21	31.442	.883	3.060	12	
VEO21	30.017	1.360	4.711	12	ve/vo2 stage 1, test 2
VCO21	1.732	.049	.170	12	vco2 stage 1, test 2
CRPE22	10.917	.514	1.782	12	central rpe stage 2, test 2
LRPE22	10.833	.575	1.992	12	local rpe stage 2, test 2
ORPE22	10.833	.534	1.850	12	overall rpe stage 2, test 2
VE22	66.817	2.382	8.252	12	ve stage 2, test 2
PVO22	78.883	2.201	7.623	12	percent vo2 max stage 2, test 2
VOL22	2.109	.048	.168	12	vo2 l min stage 2, test 2
OKG22	35.458	.642	2.224	12	vo2 ml kg min stage 2, test 2
VEO22	31.875	1.412	4.892	12	ve/vo2 stage 2, test 2
VCO22	2.117	.070	.243	12	vco2 stage 2, test 2

NUMBER OF VALID OBSERVATIONS (LISTWISE) = 8.00

VARIABLE	MEAN	S.E. MEAN	STD DEV	VALID N	LABEL
CRPE11	11.000	.627	1.773	8	central rpe stage 1, test 1
LRPE11	11.125	.718	2.031	8	local rpe stage 1, test 1
ORPE11	11.250	.750	2.121	8	overall rpe stage 1, test 1
VE11	55.462	3.033	8.579	8	ve stage 1, test 1
PVO11	82.137	1.383	3.912	8	percent vo2 max stage 1, test 1
VOL11	1.737	.056	.160	8	vo2 l min stage 1, test 1
OKG11	30.887	.995	2.813	8	vo2 ml kg min stage 1, test 2
VEO11	32.200	2.192	6.201	8	ve/vo2 stage 1, test 1
VCO11	1.744	.076	.215	8	vco2 stage 1, test 1
CRPE12	14.125	.549	1.553	8	central rpe stage 2, test 1
LRPE12	14.000	.681	1.927	8	local rpe stage 2, test 1
ORPE12	14.250	.590	1.669	8	overall rpe stage 2, test 1
VE12	69.187	3.715	10.507	8	ve stage 2, test 1
PVO12	91.450	2.170	6.137	8	percent vo2 max stage 2, test 1
VOL12	1.935	.071	.201	8	vo2 l min stage 2, test 1
OKG12	34.375	1.199	3.391	8	vo2 ml kg min stage 2, test 1
VEO12	35.925	1.906	5.392	8	ve/vo2 stage 2, test 1
VCO12	2.177	.088	.249	8	vco2 stage 2, test 1
CRPE21	11.125	.693	1.959	8	central rpe stage 1, test 2
LRPE21	11.375	.680	1.923	8	local rpe stage 1, test 2
ORPE21	11.500	.732	2.070	8	overall rpe stage 1, test 2
VE21	54.537	2.429	6.870	8	ve stage 1, test 2
PVO21	80.612	1.890	5.345	8	percent vo2 max stage 1, test 2
VOL21	1.664	.060	.169	8	vo2 l min stage 1, test 2
OKG21	29.487	1.017	2.875	8	
VEO21	32.937	1.443	4.081	8	ve/vo2 stage 1, test 2
VCO21	1.755	.087	.245	8	vco2 stage 1, test 2
CRPE22	13.500	.707	2.000	8	central rpe stage 2, test 2
LRPE22	13.875	.789	2.232	8	local rpe stage 2, test 2
ORPE22	13.875	.766	2.167	8	overall rpe stage 2, test 2
VE22	70.925	2.502	7.076	8	ve stage 2, test 2
PVO22	91.100	1.166	3.297	8	percent vo2 max stage 2, test 2
VOL22	1.882	.067	.189	8	vo2 l min stage 2, test 2
OKG22	33.350	1.043	2.950	8	vo2 ml kg min stage 2, test 2
VEO22	37.800	1.090	3.083	8	ve/vo2 stage 2, test 2
VCO22	2.241	.111	.314	8	vco2 stage 2, test 2

SUMMARY UANOVA TABLE FOR CENTRAL AND LOCAL PERCEIVED EXERTION (CRPE, LRPE)

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR CRPE

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP		172 80	228 94	172 80	12 77	13 53	1 0	18 0	0 0017
UNIV	CASES(GRP)	•	228 94	10 10	12 77	0 56	22 76	18 0	18 0	0 0
UNIV	TIME		1 51	14 06	1 51	0 78	1 94	1 0	18 0	0 1811
UNIV	GRP*TIME		3 67	14 06	3 67	0 78	4 70	1 0	18 0	0 0437
UNIV	TIME*CASES(GRP)	•	14 06	10 10	0 78	0 56	1 39	18 0	18 0	0 2451
UNIV	STAGE		127 51	11 06	127 51	0 61	207 48	1 0	18 0	0 0
UNIV	GRP*STAGE		0 67	11 06	0 67	0 61	1 10	1 0	18 0	0 3085
UNIV	STAGE*CASES(GRP)	•	11 06	10 10	0 61	0 56	1 09	18 0	18 0	0 4248
UNIV	GRAND MEAN		9052 51	10 10	9052 51	0 56	16126 54	1 0	18 0	0 0
UNIV	CASES(GRP)	•	229 94	10 10	12 77	0 56	22 76	18 0	18 0	0 0
UNIV	TIME*STAGE		0 61	10 10	0 61	0 56	1 09	1 0	18 0	0 3100
UNIV	GRP*TIME*STAGE		0 53	10 10	0 53	0 56	0 95	1 0	18 0	0 3426
UNIV	TIME*CASES(GRP)	•	14 06	10 10	0 78	0 56	1 39	18 0	18 0	0 2451
UNIV	STAGE*CASES(GRP)	•	11 06	10 10	0 61	0 56	1 09	18 0	18 0	0 4248
UNIV	TIME*STAGE*CASES(GRP)	•	10 10	****	0 56	****	****	18 0	****	****

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR LRPE

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP		174 0	266 14	174 0	14 79	11 77	1 0	18 0	0 0030
UNIV	CASES(GRP)	•	266 14	16 14	14 79	0 90	16 49	18 0	18 0	0 0
UNIV	TIME		4 51	29 97	4 51	1 66	2 71	1 0	18 0	0 1170
UNIV	GRP*TIME		2 27	29 97	2 27	1 66	1 36	1 0	18 0	0 2583
UNIV	TIME*CASES(GRP)	•	29 97	16 14	1 66	0 90	1 86	18 0	18 0	0 0993
UNIV	STAGE		99 01	15 89	99 01	0 88	112 19	1 0	18 0	0 0
UNIV	GRP*STAGE		2 85	15 89	2.85	0 88	3 23	1 0	18 0	0.0890
UNIV	STAGE*CASES(GRP)	•	15 89	16 14	0 88	0 90	0 98	18 0	18 0	0 5130
UNIV	GRAND MEAN		9309 61	16 14	9309 61	0 90	10385 41	1 0	18 0	0 0
UNIV	CASES(GRP)	•	266 14	16 14	14 79	0 90	16 49	18 0	18 0	0 0
UNIV	TIME*STAGE		0 61	16 14	0 61	0 90	0 68	1 0	18 0	0 4193
UNIV	GRP*TIME*STAGE		208330-2	16 14	208330-2	0 90	0 0	1 0	18 0	0 9621
UNIV	TIME*CASES(GRP)	•	29 97	16 14	1 66	0 90	1 86	18 0	18 0	0 0993
UNIV	STAGE*CASES(GRP)	•	15 89	16 14	0 88	0 90	0 98	18 0	18 0	0 5130
UNIV	TIME*STAGE*CASES(GRP)	•	16 14	****	0 90	****	****	18 0	****	****

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND IF SO, RESIDUAL IS USED

SUMMARY UANOVA TABLE FOR PERCENTAGE OF VO_2 Max. and VE/VO_2 RATIO (FVO and VEO)

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR PVO

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP		2511 67	2002 93	2511 67	111 27	22 57	1 0	18 0	0 [illegible]02
UNIV	CASES(GRP)	*	2002 93	116 70	111 27	6 48	17 16	18 0	18 0	0 0
UNIV	TIME		23 76	344 71	23 76	19 15	1 24	1 0	18 0	0 2800
UNIV	GRP*TIME		0 31	344 71	0 31	19 15	0 02	1 0	18 0	0 9002
UNIV	TIME*CASES(GRP)	*	344 71	116 70	19 15	6 48	2 95	18 0	18 0	0 0134
UNIV	STAGE		1952 29	219 55	1952 29	12 20	160 06	1 0	18 0	0 0
UNIV	GRP*STAGE		533330-2	219 55	533330-2	12 20	0 0	1 0	18 0	0 9835
UNIV	STAGE*CASES(GRP)	*	219 55	116 70	12 20	6 48	1 88	18 0	18 0	0 0948
UNIV	GRAND MEAN		505143 11	116 70	505143 08	6 48	77917 12	1 0	18 0	0 0
UNIV	CASES(GRP)	*	2002 93	116 70	111 27	6 48	17 16	18 0	18 0	0 0
UNIV	TIME*STAGE		0 61	116 70	0 61	6 18	0 09	1 0	18 0	0 7621
UNIV	GRP*TIME*STAGE		7 75	116 70	7 75	6 48	1 20	1 0	18 0	0 2886
UNIV	TIME*CASES(GRP)	*	344 71	116 70	19 15	6 48	2 95	18 0	18 0	0 0134
UNIV	STAGE*CASES(GRP)	*	219 55	116 70	12 20	6 48	1 88	18 0	18 0	0 0948
UNIV	TIME*STAGE*CASES(GRP)	*	116 70	....	6 48	....	....	18 0	....	....

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR VEO

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP		213 47	1738 69	213 47	96 59	2 21	1 0	18 0	0 1544
UNIV	CASES(GRP)	*	1738 69	52 49	96 59	2 92	33 13	18 0	18 0	0 0
UNIV	TIME		25880-25	255 41	25880-25	14 19	0 0	1 0	18 0	1 0
UNIV	GRP*TIME		22 75	255 41	22 75	14 19	1 60	1 0	18 0	0 2216
UNIV	TIME*CASES(GRP)	*	255 41	52 49	14 19	2 92	4 87	18 0	18 0	0 0008
UNIV	STAGE		150 15	47 19	150 15	2 62	57 27	1 0	18 0	0 0
UNIV	GRP*STAGE		32 19	47 19	32 19	2 62	12 28	1 0	18 0	0 0025
UNIV	STAGE*CASES(GRP)	*	47 19	52 49	2 62	2 92	0 90	18 0	18 0	0 5881
UNIV	GRAND MEAN		85621 70	52 49	85621 70	2 92	29363 29	1 0	18 0	0 0
UNIV	CASES(GRP)	*	1738 69	52 49	96 59	2 92	33 13	18 0	18 0	0 0
UNIV	TIME*STAGE		2 05	52 49	2 05	2 92	0 70	1 0	18 0	0 4130
UNIV	GRP*TIME*STAGE		0 83	52 49	0 83	2 92	0 28	1 0	18 0	0 6013
UNIV	TIME*CASES(GRP)	*	255 41	52 49	14 19	2 92	4 87	18 0	18 0	0 0008
UNIV	STAGE*CASES(GRP)	*	47 19	52 49	2 62	2 92	0 90	18 0	18 0	0 5881
UNIV	TIME*STAGE*CASES(GRP)	*	52 49	....	2 92	....	....	18 0	....	....

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND IF SO, RESIDUAL IS USED

SUMMARY UANOVA TABLE FOR OVERALL PERCEIVED EXERTION (ORPE) AND MINUTE VENTILATION (VE)

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR ORPE

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFM	DFE	PROB
UNIV	GRP		174.0	266.14	174.0	14.79	11.77	1.0	18.0	0.0030
UNIV	CASES(GRP)	*	266.14	16.22	14.79	0.90	16.41	18.0	18.0	0.0
UNIV	TIME		1.51	16.72	1.51	0.93	1.63	1.0	18.0	0.2181
UNIV	GRP*TIME		1.52	16.72	1.52	0.93	1.64	1.0	18.0	0.2172
UNIV	TIME*CASES(GRP)	*	16.72	16.22	0.93	0.90	1.03	18.0	18.0	0.4747
UNIV	STAGE		103.51	12.97	103.51	0.72	143.67	1.0	18.0	0.0
UNIV	GRP*STAGE		2.27	12.97	2.27	0.72	3.15	1.0	18.0	0.0929
UNIV	STAGE*CASES(GRP)	*	12.97	16.22	0.72	0.90	0.80	18.0	18.0	0.6799
UNIV	GRAND MEAN		9526.61	16.22	9526.61	0.90	10572.88	1.0	18.0	0.0
UNIV	CASES(GRP)	*	266.14	16.22	14.79	0.90	16.41	18.0	18.0	0.0
UNIV	TIME*STAGE		1.51	16.22	1.51	0.90	1.68	1.0	18.0	0.2115
UNIV	GRP*TIME*STAGE		0.02	16.22	0.02	0.90	0.02	1.0	18.0	0.8869
UNIV	TIME*CASES(GRP)	*	16.72	16.22	0.93	0.90	1.03	18.0	18.0	0.4747
UNIV	STAGE*CASES(GRP)	*	12.97	16.22	0.72	0.90	0.80	18.0	18.0	0.6799
UNIV	TIME*STAGE*CASES(GRP)	*	16.22	****	0.90	****	****	18.0	****	****

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR VE

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFM	DFE	PROB
UNIV	GRP		4.86	5609.75	4.86	311.65	0.02	1.0	18.0	0.9020
UNIV	CASES(GRP)	*	5609.75	155.71	311.65	8.65	36.03	18.0	18.0	0.0
UNIV	TIME		4.85	453.15	4.85	25.18	0.19	1.0	18.0	0.6659
UNIV	GRP*TIME		10.77	453.15	10.77	25.18	0.43	1.0	18.0	0.5213
UNIV	TIME*CASES(GRP)	*	453.15	155.71	25.18	8.65	2.91	18.0	18.0	0.0144
UNIV	STAGE		3237.24	191.96	3237.24	10.66	303.55	1.0	18.0	0.0
UNIV	GRP*STAGE		72.62	191.96	72.62	10.66	6.81	1.0	18.0	0.0177
UNIV	STAGE*CASES(GRP)	*	191.96	155.71	10.66	8.65	1.23	18.0	18.0	0.3308
UNIV	GRAND MEAN		309768.50	155.71	309768.45	8.65	35808.20	1.0	18.0	0.0
UNIV	CASES(GRP)	*	5609.75	155.71	311.65	8.65	36.03	18.0	18.0	0.0
UNIV	TIME*STAGE		1.13	155.71	1.13	8.65	0.13	1.0	18.0	0.7232
UNIV	GRP*TIME*STAGE		15.95	155.71	15.95	8.65	1.84	1.0	18.0	0.1913
UNIV	TIME*CASES(GRP)	*	45[illegible].15	155.71	25.18	8.65	2.91	18.0	18.0	0.0144
UNIV	STAGE*CASES(GRP)	*	[illegible].96	155.71	10.66	8.65	1.23	18.0	18.0	0.3309
UNIV	TIME*STAGE*CASES(GRP)	*	[illegible].71	****	8.65	****	****	18.0	****	****

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND. IF SO, RESIDUAL IS USED

SUMMARY UANOVA TABLE FOR OXYGEN CONSUMPTION ML/KG./MIN (OKC) and L/MIN (VOL)

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR: OKG

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFM	DFE	PROB
UNIV	GRP		25 12	401 07	25 12	22 28	1 13	1 0	18 0	0 3024
UNIV	CASES(GRP)	*	401 07	18 88	22 28	1 05	21 2[illegible]	[illegible]	18 0	0 0
UNIV	TIME		0 44	110 30	0 44	6 13	[illegible]	[illegible]	18 0	0 7929
UNIV	GRP*TIME		15 12	110 30	15 12	6 13	[illegible]	[illegible]	18 0	0 1336
UNIV	TIME*CASES(GRP)	*	110 30	18 88	6 13	1 05	[illegible]	[illegible]	18 0	0 0002
UNIV	STAGE		325 22	30 67	325 22	1 70	[illegible]	1 0	18 0	0 0
UNIV	GRP*STAGE		1 70	30 67	1 70	1 70	[illegible]	1 0	18 0	0 3306
UNIV	STAGE*CASES(GRP)	*	30 67	18 88	1 70	1 05	1 62	18 0	18 0	0 1562
UNIV	GRAND MEAN		85602 07	18 88	85602 08	1 05	81607 62	1 0	18 0	0 0
UNIV	CASES(GRP)	*	401 07	18 88	22 28	1 05	21 24	18 0	18 0	0 0
UNIV	TIME*STAGE		0 12	18 88	0 12	1 05	0 11	1 0	18 0	0 7390
UNIV	GRP*TIME*STAGE		0 94	18 88	0 94	1 05	0 89	1 0	18 0	0 3573
UNIV	TIME*CASES(GRP)	*	110 30	18 88	6 13	1 05	5 84	18 0	18 0	0 0002
UNIV	STAGE*CASES(GRP)	*	30 67	18 88	1 70	1 05	1 62	18 0	18 0	0 1562
UNIV	TIME*STAGE*CASES(GRP)	*	18 88	****	1 05	****	****	18 0	****	****

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR VOL

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFM	DFE	PROB
UNIV	GRP		0 62	1 28	0 62	0 07	8 75	1 0	18 0	0 0084
UNIV	CASES(GRP)	*	1 28	0 08	0 07	447100-2	15 92	18 0	18 0	0 0
UNIV	TIME		420500-2	0 37	420500-2	0 02	0 20	1 0	18 0	0 6564
UNIV	GRP*TIME		0 03	0 37	0 03	0 02	1 53	1 0	18 0	0 2314
UNIV	TIME*CASES(GRP)	*	0 37	0 08	0 02	447100-2	4 60	18 0	18 0	0 0011
UNIV	STAGE		1 09	0 14	1.09	761490 2	142 58	1 0	18 0	0 0
UNIV	GRP*STAGE		825020-2	0 14	825020-2	761490 2	1 08	1 0	18 0	0 3117
UNIV	STAGE*CASES(GRP)	*	0 14	0 08	761490 2	447100 2	1 70	18 0	19 0	0 1340
UNIV	GRAND MEAN		292 69	0 08	292 69	447100-2	65463 81	1 0	18 0	0 0
UNIV	CASES(GRP)	*	1 28	0 08	0 07	447100 2	15 92	18 0	18 0	0 0
UNIV	TIME*STAGE		978990-3	0 08	978990-3	447100-2	0 22	1 0	18 0	0 6453
UNIV	GRP*TIME*STAGE		414180-2	0 08	414180-2	447100-2	0 93	1 0	18 0	0 3486
UNIV	TIME*CASES(GRP)	*	0 37	0 08	0 02	447100 2	4 60	18 0	18 0	0 0011
UNIV	STAGE*CASES(GRP)	*	0 14	0 08	761490-2	447100-2	1 70	18 0	18 0	0 1340
UNIV	TIME*STAGE*CASES(GRP)	*	0 08	****	447100-2	****	****	18 0	****	****

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND IF SO, RESIDUAL IS USED

SUMMARY UANOVA TABLE FOR EXPIRED CARBON DIOXIDE (VCO)

HIERARCHICAL   SUMMARY TABLE OF F-RATIOS FOR: VCO

TYPE	PART OF MODEL	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRP	13333D-2	2.97	13333D-2	0.16	0.01	1.0	18.0	0.9293
UNIV	CASES(GRP)	2.97	0.16	0.16	91496D-2	18.02	18.0	18.0	0.0
UNIV	TIME	0.07	0.67	0.07	0.04	1.98	1.0	18.0	0.1768
UNIV	GRP*TIME	0.13	0.67	0.13	0.04	3.45	1.0	18.0	0.0789
UNIV	TIME*CASES(GRP)	0.67	0.16	0.04	91496D-2	4.08	18.0	18.0	0.0023
UNIV	STAGE	3.57	0.31	3.57	0.02	209.83	1.0	18.0	0.0 *
UNIV	GRP*STAGE	0.02	0.31	0.02	0.02	1.09	1.0	18.0	0.3111
UNIV	STAGE*CASES(GRP)	0.31	0.16	0.02	91496D-2	1.86	18.0	18.0	0.0985
UNIV	GRAND MEAN	315.02	0.16	315.02	91496D-2	34429.64	1.0	18.0	0.0
UNIV	CASES(GRP)	2.97	0.16	0.16	91496D-2	18.02	18.0	18.0	0.0
UNIV	TIME*STAGE	10125D-3	0.16	10125D-3	91496D-2	0.01	1.0	18.0	0.9174
UNIV	GRP*TIME*STAGE	76799D-2	0.16	76799D-2	91496D-2	0.84	1.0	18.0	0.3717
UNIV	TIME*CASES(GRP)	0.67	0.16	0.04	91496D-2	4.08	18.0	18.0	0.0023
UNIV	STAGE*CASES(GRP)	0.31	0.16	0.02	91496D-2	1.86	18.0	18.0	0.0985
UNIV	TIME*STAGE*CASES(GRP)	0.16	****	91496D-2	****	****	18.0	****	****

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND. IF SO: RESIDUAL IS USED

APPENDIX G

PEARSON CORRELATION MATRICES - ALL GROUPS

CORRELATION MATRICES (MID-TEST) (TRAINING GROUP, n=12)

- - - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - -

	CRPE11	LRPE11	ORPE11	VE11	PVO11	VOL11	OKG11	VEO11	VCO11
CRPE11									
LRPE11	9449 (12) P= 000								
ORPE11	9293 (12) P= 000	.8989 (12) P= .000							
VE11	.3951 (12) P= .102	.3970 (12) P= .101	3909 (12) P= 104						
PVO11	-.2215 (12) P= .245	- 2223 (12) P= .244	- 1753 (12) P= 293	4368 (12) P= 078					
VOL11	-.4471 (12) P= 073	- 5237 (12) P= 040	- 2866 (12) P= .183	- 0442 (12) P= 446	0013 (12) P= 498				
OKG11	- 3110 (12) P= .163	- 3398 (12) P= .140	- 1339 (12) P= 339	1654 (12) P= 304	4203 (12) P= .087	6588 (12) P= 010			
VEO11	.5284 (12) P= .039	.5597 (12) P= 029	4733 (12) P= 060	9275 (12) P= 000	4010 (12) P= 098	- 4107 (12) P= 092	- 0640 (12) P= 422		
VCO11	- 0909 (12) P= .389	- .1475 (12) P= 324	- 1106 (12) P= 366	5089 (12) P= 046	2605 (12) P= 207	4568 (12) P= 068	1452 (12) P= 326	2625 (12) P= 205	

	CRPE12	LRPE12	ORPE12	VE12	PVO12	VOL12	OKG12	VEO12	VCO12
CRPE12									
LRPE12	9340 (12) P= 000								
ORPE12	9849 (12) P= .000	9675 (12) P= 000							
VE12	4968 (12) P= 060	5691 (12) P= 027	4967 (12) P= 050						
PVO12	-.0988 (12) P= 380	-.0391 (12) P= .452	- 1294 (12) P= 344	5476 (12) P= 033					
VOL12	- 5082 (12) P= 046	- 5023 (12) P= 048	- 4803 (12) P= 057	- 2162 (12) P= 250	- 4228 (12) P= 085				
OKG12	- 4521 (12) P= 070	- 2480 (12) P= 219	- 3994 (12) P= 099	1172 (12) P= 358	1809 (12) P= 087	2449 (12) P= 221			
VEO12	.5928 (12) P= .021	.6562 (12) P= 010	5868 (12) P= 022	9603 (12) P= 000	6105 (12) P= 018	- 4777 (12) P= 058	0465 (12) P= 443		
VCO12	- 0823 (12) P= 400	- 1812 (12) P= 287	- 1336 (12) P= 339	2432 (12) P= 223	2339 (12) P= 232	3951 (12) P= 102	- 2985 (12) P= 173	0937 (12) P= 386	

(COEFFICIENT / (CASES) / 1-TAILED SIG)   " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

CORRELATION MATRICES (POST -TEST) TRAINING GROUP (n=12)

- - - - - - - - P E A R S O N C O R R E L A T I O N C O E F F I C I E N T S - - - - - - - -

	CRPE21	LRPE21	ORPE21	VE21	PVO21	VOL21	OKG21	VEO21	VCO21
CRPE21									
LRPE21	9197 (12) P= 000								
ORPE21	9635 (12) P= 000	9673 (12) P= 000							
VE21	6806 (12) P= 007	7556 (12) P= 002	7909 (12) P= 001						
PVO21	2464 (12) P= 220	3364 (12) P= 142	3059 (12) P= 167	3743 (12) P= 115					
VOL21	- 1047 (12) P= 373	- 1704 (12) P= 298	- 1492 (12) P= 322	0366 (12) P= 455	- 3197 (12) P= 156				
OKG21	0818 (12) P= 400	0651 (12) P= .420	0983 (12) P= 381	3904 (12) P= 105	4044 (12) P= 096	4717 (12) P= 061			
VEO21	6724 (12) P= 008	7698 (12) P= 002	7934 (12) P= 001	9050 (12) P= 000	4761 (12) P= 059	- 3912 (12) P= 104	1536 (12) P= 317		
VCO21	0488 (12) P= 440	- 1006 (12) P= 378	0018 (12) P= 498	2125 (12) P= 254	- 3156 (12) P= 159	8048 (12) P= 001	2017 (12) P= 265	- 1484 (12) P= 323	

	CRPE22	LRPE22	ORPE22	VE22	PVO22	VOL22	OKG22	VEO22	VCO22
CRPE22									
LRPE22	9433 (12) P= 000								
ORPE22	.9881 (12) P= .000	9781 (12) P= .000							
VE22	6642 (12) P= 009	.6134 (12) P= .017	.6753 (12) P= .008						
PVO22	.1097 (12) P= .367	-.0110 (12) P= .487	.0791 (12) P= .404	4198 (12) P= 087					
VOL22	-.2767 (12) P= .192	-.2830 (12) P= .186	-.2637 (12) P= .204	-.0401 (12) P= 451	- 0601 (12) P= 426				
OKG22	1298 (12) P= .344	.0496 (12) P= .439	1020 (12) P= 376	3064 (12) P= .166	2998 (12) P= .172	0386 (12) P= 453			
VEO22	.7017 (12) P= .005	.6627 (12) P= .009	7055 (12) P= .005	8475 (12) P= 000	3561 (12) P= .128	- 5592 (12) P= 029	2292 (12) P= 237		
VCO22	.0456 (12) P= 444	.0307 (12) P= .462	.0614 (12) P= .425	1504 (12) P= 320	0280 (12) P= 466	.9201 (12) P= 000	0572 (12) P= 430	- 3486 (12) P= 133	

(COEFFICIENT / (CASES) / 1-TAILED SIG) " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

CORRELATION MATRICES MID-TEST NON-TRAINING GROUP (n=8)

- - - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - -

	CRPE11	LRPE11	ORPE11	VE11	PVO11	VOL11	OKG11	VEO11	VCO11
CRPE11									
LRPE11	.7538 (8) P= .015								
ORPE11	.9117 (8) P= .001	.9201 (8) P= .001							
VE11	-.1503 (8) P= .361	-.0063 (8) P= .494	-.1344 (8) P= .375						
PVO11	-.0371 (8) P= .465	-.3890 (8) P= .170	-.3593 (8) P= .191	.3070 (8) P= .230					
VOL11	-.4190 (8) P= .151	-.1355 (8) P= .375	-.2763 (8) P= .254	-.1067 (8) P= .401	-.5873 (8) P= .063				
OKG11	-.1117 (8) P= .396	.1403 (8) P= .370	-.0425 (8) P= .460	-.4269 (8) P= .146	-.3169 (8) P= .222	.7118 (8) P= .024			
VEO11	.0884 (8) P= .418	.0817 (8) P= .424	.0489 (8) P= .454	.8566 (8) P= .003	.5134 (8) P= .097	-.6006 (8) P= .058	-.7154 (8) P= .023		
VCO11	-.1048 (8) P= .402	-.0241 (8) P= .477	-.2369 (8) P= .286	.6247 (8) P= .049	.4856 (8) P= .111	.1957 (8) P= .321	.2661 (8) P= .262	.3666 (8) P= .186	

	CRPE12	LRPE12	ORPE12	VE12	PVO12	VOL12	OKG12	VEO12	VCO12
CRPE12									
LRPE12	.3342 (8) P= .209								
ORPE12	.8131 (8) P= .007	.6662 (8) P= .036							
VE12	.1393 (8) P= .371	.0734 (8) P= .431	-.1546 (8) P= .357						
PVO12	.1762 (8) P= .338	-.1039 (8) P= .403	-.0572 (8) P= .447	.3647 (8) P= .187					
VOL12	-.0573 (8) P= .446	.5208 (8) P= .093	-.0512 (8) P= .452	.3977 (8) P= .165	-.0929 (8) P= .413				
OKG12	.3724 (8) P= .182	.7890 (8) P= .010	.4883 (8) P= .110	.0578 (8) P= .446	.0408 (8) P= .462	.7581 (8) P= .014			
VEO12	.2061 (8) P= .312	-.3148 (8) P= .224	-.1056 (8) P= .402	.7451 (8) P= .017	.4473 (8) P= .133	-.3109 (8) P= .227	-.4775 (8) P= .116		
VCO12	.2964 (8) P= .238	.3987 (8) P= .164	-.0326 (8) P= .469	.7809 (8) P= .011	.4112 (8) P= .156	.6111 (8) P= .054	.5211 (8) P= .093	.3518 (8) P= .196	

(COEFFICIENT / (CASES) / 1-TAILED SIG) " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

CORRELATION MATRICES POST-TEST NON-TRAINING GROUP

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - -

	CRPE21	LRPE21	ORPE21	VE21	PVO21	VOL21	OKG21	VEO21	VCO21
CRPE21									
LRPE21	7063 (8) P= 025								
ORPE21	9333 (8) P= 000	8435 (8) P= 004							
VE21	- 3931 (8) P= 168	- 3106 (8) P= 227	- 4997 (8) P= 104						
PVO21	6804 (8) P= 032	0203 (8) P= 481	4564 (8) P= .128	- 2121 (8) P= 307					
VOL21	- 4862 (8) P= 111	- 8339 (8) P= 005	- 7514 (8) P= 016	4374 (8) P= 139	1122 (8) P= 396				
OKG21	- 0124 (8) P= 488	- .3970 (8) P= 165	- .3444 (8) P= .202	3460 (8) P= 201	3867 (8) P= 172	7788 (8) P= 011			
VEO21	- 0060 (8) P= 494	3730 (8) P= 181	1108 (8) P= 397	6467 (8) P= 042	- 3199 (8) P= .220	- 4014 (8) P= 162	- 3146 (8) P= 224		
VCO21	- 3256 (8) P= 216	- 4925 (8) P= 108	- .5545 (8) P= .077	4949 (8) P= 106	0474 (8) P= 456	8421 (8) P= 004	7092 (8) P= 024	- 2314 (8) P= 291	

	CRPE22	LRPE22	ORPE22	VE22	PVO22	VOL22	OKG22	VEO22	VCO22
CRPE22									
LRPE22	5600 (8) P= 074								
ORPE22	8405 (8) P= 004	9118 (8) P= .001							
VE22	- .2473 (8) P= 277	- 4846 (8) P= 112	- 4506 (8) P= 131						
PVO22	.8102 (8) P= 007	.5552 (8) P= .077	7517 (8) P= .016	- .2509 (8) P= 274					
VOL22	- .5958 (8) P= 060	- 3844 (8) P= 174	- 5455 (8) P= .081	6640 (8) P= 036	- 2383 (8) P= 285				
OKG22	- 3753 (8) P= .180	- .0705 (8) P= .434	- .2737 (8) P= .256	.2867 (8) P= 246	0893 (8) P= 417	7552 (8) P= 015			
VEO22	4148 (8) P= .153	- .1142 (8) P= .394	.1155 (8) P= .393	3944 (8) P= 167	- .0266 (8) P= .475	- 4247 (8) P= 147	- 5751 (8) P= 068		
VCO22	- 3881 (8) P= 171	- 1099 (8) P= .398	- 2581 (8) P= 269	5275 (8) P= 090	- 1158 (8) P= 392	9053 (8) P= 001	6288 (8) P= 047	- .4817 (8) P= 113	

(COEFFICIENT / (CASES) / 1-TAILED SIG) " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

CORRELATION MATRICES (POST-TEST) COMBINED GROUPS

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - -

	CRPE21	LRPE21	ORPE21	VE21	PVO21	VOL21	OKG21	VEO21	VCO21
CRPE21									
LRPE21	8730 (20) P= 000								
ORPE21	9599 (20) P= 000	9419 (20) P= .000							
VE21	1592 (20) P= 251	3201 (20) P= 084	2455 (20) P= 148						
PVO21	6484 (20) P= 001	4810 (20) P= 016	5753 (20) P= 004	0471 (20) P= 422					
VOL21	- 5290 (20) P= 008	- 5810 (20) P= 004	- 5792 (20) P= .004	2216 (20) P= 174	- 4990 (20) P= 013				
OKG21	- 1506 (20) P= 263	- 2238 (20) P= 171	- 2111 (20) P= 186	3880 (20) P= 045	0402 (20) P= 433	6447 (20) P= 001			
VEO21	5044 (20) P= 012	6907 (20) P= 000	-6187 (20) P= 002	7392 (20) P= 000	3651 (20) P= 057	- 4864 (20) P= 015	- 1076 (20) P= 326		
VCO21	- 0794 (20) P= 370	- 1998 (20) P= 199	- 1877 (20) P= 214	3181 (20) P= 086	- 0622 (20) P= 397	6251 (20) P= 002	3855 (20) P= 047	- 1514 (20) P= 262	

	CRPE22	LRPE22	ORPE22	VE22	PVO22	VOL22	OKG22	VEO22	VCO22
CRPE22									
LRPE22	8519 (20) P= 000								
ORPE22	.9481 (20) P= .000	9669 (20) P= 000							
VE22	.3998 (20) P= 040	.3080 (20) P= 093	3394 (20) P= 072						
PVO22	.5567 (20) P= .005	.4889 (20) P= 014	5626 (20) P= 005	3772 (20) P= .051					
VOL22	-.6052 (20) P= .002	-.5506 (20) P= .006	[illegible] (20) P= 003	.0372 (20) P= .438	- 4463 (20) P= .024				
OKG22	-.3159 (20) P= .087	-.2439 (20) P= 150	-.3065 (20) P= .094	.1548 (20) P= .257	-.1393 (20) P= 279	5145 (20) P= 010			
VEO22	.7284 (20) P= 000	.6143 (20) P= 002	.6776 (20) P= .001	.7215 (20) P= 000	.5820 (20) P= 004	- 6597 (20) P= 001	- 2650 (20) P= 129		
VCO22	0049 (20) P= .492	.1096 (20) P= 323	0702 (20) P= 384	3422 (20) P= 070	1566 (20) P= 255	6120 (20) P= 002	2271 (20) P= 168	-.1610 (20) P= .249	

(COEFFICIENT / (CASES) / 1-TAILED SIG) " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

CORRELATION MATRICES (MID-TEST) COMBINED GROUPS (n=20)

- - - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - -

	CRPE11	LRPE11	ORPE11	VE11	PVO11	VOL11	OKG11	VEO11	VCO11
CRPE11									
LRPE11	.9199 (20) P= .000								
ORPE11	.9499 (20) P= .000	.9424 (20) P= .000							
VE11	.1158 (20) P= .313	.1601 (20) P= .250	.1105 (20) P= .321						
PVO11	.4128 (20) P= .035	.3194 (20) P= .085	.3416 (20) P= .070	.2221 (20) P= .173					
VOL11	-.5217 (20) P= .009	-.4704 (20) P= .018	-.4075 (20) P= .037	-.0402 (20) P= .433	-.3401 (20) P= .071				
OKG11	.1428 (20) P= .274	-.0866 (20) P= .358	-.0448 (20) P= .426	-.0307 (20) P= .449	.1767 (20) P= .228	.6274 (20) P= .002			
VEO11	.3316 (20) P= .0[illegible]	.3488 (20) P= .066	.2874 (20) P= .110	.8894 (20) P= .000	.3511 (20) P= .065	-.4843 (20) P= .015	-.2994 (20) P= .100		
VCO11	-.2132 (20) P= .183	-.2107 (20) P= .186	-.2548 (20) P= .139	.5429 (20) P= .007	.0451 (20) P= .425	.4047 (20) P= .038	.1723 (20) P= .234	.2695 (20) P= .125	

	CRPE12	LRPE12	ORPE12	VE12	PVO12	VOL12	OKG12	VEO12	VCO12
CRPE12									
LRPE12	.8801 (20) P= .000								
ORPE12	.9704 (20) P= .000	.9367 (20) P= .000							
VE12	.3206 (20) P= .084	.3441 (20) P= .069	.2710 (20) P= .124						
PVO12	.4055 (20) P= .038	.3710 (20) P= .054	.3368 (20) P= .073	.4031 (20) P= .039					
VOL12	-.5253 (20) P= .009	-.3506 (20) P= .065	-.5045 (20) P= .012	.0416 (20) P= .431	.4842 (20) P= .015				
OKG12	-.1944 (20) P= .206	.0429 (20) P= .429	-.1364 (20) P= .283	.0816 (20) P= .366	-.0012 (20) P= .498	.5469 (20) P= .006			
VEO12	.5341 (20) P= .008	.4502 (20) P= .023	.4754 (20) P= .017	.8677 (20) P= .000	.5909 (20) P= .003	-.4530 (20) P= .022	-.2075 (20) P= .190		
VCO12	-.0910 (20) P= .351	-.0945 (20) P= .346	-.1690 (20) P= .238	.4269 (20) P= .030	.1218 (20) P= .305	.5102 (20) P= .011	.1328 (20) P= .298	.1305 (20) P= .292	

(COEFFICIENT / (CASES) / 1-TAILED SIG)   " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

APPENDIX H

REGRESSION ANALYSIS

* * * * MULTIPLE REGRESSION * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable ORPE22 overall rpe stage 2, test 2

Beginning Block Number 1 Method Stepwise

Variable(s) Entered on Step Number 1 VE022 ve/vo2 stage 2, test 2

Multiple R	67755
R Square	45908
Adjusted R Square	42903
Standard Error	1 85860

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	52 77113	52 77113
Residual	18	62 17887	3 45438

F = 15 27658 Signif F = 0010

------------ Variables in the Equation ------------

Variable	B	SE B	Beta	T	Sig T
VE022	325436	083263	677554	3 909	0010
(Constant)	905433	2 881476		314	7570

------------ Variables not in the Equation ------------

Variable	Beta In	Partial	Min Toler	T	Sig T
VE22	311680	-.293428	479424	-1 266	2227
PVO22	254392	281261	661219	1 208	2434
VOL22	-270183	-276092	564838	-1 184	2526
OKG22	-136549	-179025	929793	-750	4634
VCO22	184036	246962	974069	1 051	3081
TRAING	343797	-380280	661816	-1 695	1083

End Block Number 1 PIN 050 Limits reached

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable   ORPE21   overall rpe stage 1, test 2

Beginning Block Number 1   Method   Stepwise

Variable(s) Entered on Step Number 1   VE021   ve/vo2 stage 1, test 2

Multiple R	61869
R Square	38278
Adjusted R Square	34849
Standard Error	1 95050

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	42 46962	42 46962
Residual	18	68 48038	3 80447

F = 11 16310   Signif F = 0036

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
VE021	325151	097318	618693	3 341	0036
(Constant)	089838	3 066040		- 029	9769

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
VE21	- 466897	- 400269	453630	-1 801	0895
PVO21	403153	477733	866702	2 242	0386
VOL21	- 364528	- 405397	763375	-1 828	0851
OKG21	- 146169	- 184972	988421	- 776	4484
VCO21	- 096218	- 121061	977083	- 503	6215
TRAING	- 339757	- 409828	898059	-1 852	0814

. . . .

Variable(s) Entered on Step Number 2   PVO21   percent vo2 max stage 1, test 2

Multiple R	72364
R Square	52365
Adjusted R Square	46761
Standard Error	1 76320

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	58 09884	29 04942
Residual	17	52 85116	3 10889

F = 9 34398   Signif F = 0018

Equation Number 1   Dependent Variable   ORPE21   overall rpe stage 1, test 1

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
VE021	247796	094496	471502	2 622	0178
PVO21	125689	056057	403153	2 242	0386
(Constant)	-6 986691	4 140483		-1 687	1098

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
VE21	- 307741	- 280714	344283	-1 170	2582
VOL21	- 230829	- 268431	644187	-1 115	2815
OKG21	- 179907	- 258196	851727	-1 069	3008
VCO21	- 093376	- 133729	850078	- 540	5968
TRAING	- 135022	- 137636	477687	- 55[illegible]	5860

End Block Number 1   PIN = 050 Limits reached

*** * * * MULTIPLE REGRESSION * * * ***

Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable.. ORPE12   overall rpe stage 2, test 1

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number 1.. TRAING

Multiple R	.64123
R Square	.41117
Adjusted R Square	.37846
Standard Error	2.26588

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	64.53333	64.53333
Residual	18	92.41667	5.13426

F = 12.56816   Signif F = .0023

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
TRAING	-3.666667	1.034233	-.641226	-3.545	.0023
(Constant)	14.250000	.801113		17.788	.0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
VE12	.248839	.324084	.998774	1.412	.1758
PVO12	-.108393	-.109961	.605987	-.456	.6541
VOL12	-.247521	-.280173	.754427	-1.203	.2453
OKG12	-.045852	-.059143	.979661	-.244	.8099
VEO12	.324220	.406398	.925150	1.834	.0842
VCO12	-.062532	-.080320	.971482	-.332	.7438

End Block Number 1   PIN = .050 Limits reached.

*** * * * MULTIPLE REGRESSION * * * ***

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable ORPE11 overall rpe stage 1, test 1

Beginning Block Number 1 Method Stepwise

Variable(s) Entered on Step Number 1 TRAING

Multiple R	61775
R Square	38162
Adjusted R Square	34727
Standard Error	1 91727

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	40 83333	40 83333
Residual	18	66 16667	3 67593

F = 11 10831 Signif F = 0037

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
TRAING	[illegible]	875110	617754	-3 [illegible]	0037
(Constant)	14 250000	877857		16 586	0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
VE11	151161	191821	995797	806	4315
PWO11	- 261857	- 222922	448159	- 943	3590
VOL11	- 233390	- 281123	897190	-1 208	2437
OKG11	- 074329	- 094415	997737	- 391	7006
VEO11	232193	294001	991418	1 268	2218
VCO11	- 127704	- 158586	953617	- 662	5167

End Block Number 1 PIN = 050 Limits reached

AUG 2 1 198

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DEPARTMENT OF ATHLETICS,
UNIVERSITY OF ALBERTA,
EDMONTON,
ALBERTA,
CANADA,
T6G 2H9.

13 August 1986

Dear sir,

I am in the final stages of completing my Master's thesis entitled:
'The relationships between perceived exertion, fitness and selected physiological parameters'.

In the thesis I wish to use two illustrations from your journal, these are:

The relative contribution of central and local cues to perceived exertion as, a) a function of time, and b) as a function of exercise intensity.

These two diagrams are taken from: Robertson R.J., (1982). Central signals of perceived exertion during dynamic exercise. Med. Sci. Sports and Exerc., Vol. 14, No. 5, pp. 390-396.

I am therefore asking your permission to incorporate these illustrations in my thesis. Enclosed is a copy of the relevant sections of the text. I would be most grateful if I could use these diagrams since I feel they are an essential part of my review of literature.

Yours sincerely,

Jeremy Rose

Jeremy Rose

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HEALTH, PHYSICAL AND RECREATION EDUCATION
Human Energy Research Laboratory

September 23, 1986

Mr. Jeremy Rose
Department of Athletics
University of Alberta
Edmonton, Alberta
CANADA T6G 2H9

Dear Mr. Rose:

By way of this letter, I grant you permission to reprint Figures 1 and 9 from my article "Central signals of perceived exertion during dynamic exercise" - (Med. Sci. Sports and Exercise, Vol. 14, No. 5, pp. 390-396) in your thesis literature review. However, if you publish the literature review, permission to use the Figures will have to be obtained from the editor of MSSE.

Good luck with your thesis.

Sincerely,

Robert J. Robertson, Ph.D.
Director - HERL

RJR/dmf

PITTSBURGH, PA 15261

AUG 19 1986

DEPARTM[redacted]ATHLETICS,
UNIVER[redacted]ALBERTA,
E[redacted]TON,
ALBERTA,
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13 August 1986

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In the thesis I wish to use three illustrations from your publication entitled:
Physical Work and Effort. Edited by G.A.V. Borg. Pergamon Press, Oxford, England. 1977.

The illustrations are as follows:

1. The Three Effort Continua. Page 5. Taken from the general introduction: Psychophysiological studies of the three effort continua. G.A.V. Borg. pp. 39-47.
2. The Borg 15-point scale (p.372), and
3. A model for differentiated perceived exertion, (p.380). Both taken from Pandolf K.B., Psychological and physiological factors influencing perceived exertion, pp. 371-382.

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Yours sincerely,

Jeremy Rose

P.T.O →

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