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The Use of Subjective Ratings of Perceived Exertion (RPE) to Estimate Fixed Blood Lactate Concentrations During Incremental Cycle Ergometer Exercise

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THE USE OF SUBJECTIVE RATINGS OF PERCEIVED EXERTION (RPE) TO ESTIMATE FIXED BLOOD LACTATE CONCENTRATIONS DURING INCREMENTAL CYCLE ERGOMETER EXERCISE.

By

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USE OF THESIS

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Date 6/12/96

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ABSTRACT

Prescription of exercise intensity based on blood lactate concentration has become widely accepted in recent years. The methods used to directly measure blood lactate concentration however, can be costly, time consuming and potentially hazardous to both subject and tester. Recent studies indicate that a strong relationship exists between subjective feelings of strain experienced during exercise and changes in the appearance of blood lactate. This raises the possibility that subjective ratings of perceived exertion (RPE) can be used to simply and effectively estimate and monitor appropriate exercise intensity based on blood lactate concentration.

In order to test this theory two groups of subjects, high active (HA) and low active (LA) were asked to complete a continuous incremental cycle ergometer protocol. Heart rate, blood lactate, differentiated (overall) and undifferentiated (central and local) RPE values were measured at the completion of each workload. At exercise intensities corresponding to 2.0, 2.5 and 4.0 mmol blood lactate, no statistically significant differences were found between the groups for undifferentiated RPE values, however low active individuals consistently rated exercise intensity corresponding to each of the blood lactate conditions as being easier than the high active group (mean overall RPE at exercise intensity corresponding to 4.0 mmol blood lactate was 15.7±0.4 for HA compared to 14.0±0.5 for LA). Higher RPE responses from the high active group occurred due to the fact that increases in the

appearance of blood lactate were observed closer to maximal relative exercise intensity for individuals in this group (4.0 mmol blood lactate occurred at 80.3% maximum heart rate for HA and 73.4% maximum heart rate for LA). Results indicate that RPE values of between 9 and 15 will result in reliable estimation of training intensities required for improvements in cardiorespiratory fitness and endurance performance based on the blood lactate response to exercise but that consideration should be given to potential modification of effort sense which may only be experienced under extreme physiological conditions.

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DEFINITION OF TERMS

RPE:	Rating of perceived exertion. A subjective measure of the level of exertion obtained from participants during exercise.
mmol:	Millimolar
LT:	Lactate threshold. Usually defined as the highest workload which can be attained during exercise before an increase in the appearance of blood lactate is observed.
OBLA:	Onset of blood lactate accumulation. The workload observed during exercise corresponding to 4.0 mmol blood lactate concentration.
VE:	Minute ventilation. The amount of air expired in one minute.
VO_2 max:	The maximal amount of oxygen that can be consumed per u unit of time
max HR	Maximum heart rate
BPM	Beats per minute (Heart Rate)
HA	High active
LA	Low active

CHAPTER ONE

INTRODUCTION

1.1 Background To The Study

Prescription of exercise intensities that will produce optimal improvements in cardiorespiratory fitness and endurance performance can be based on a variety of physiological and psychological responses to exercise (Weltman, 1995, p.5). Traditionally, popular methods for determining beneficial exercise intensities have been based on a fixed percentage of maximal oxygen consumption (VO_2 max) or a fixed percentage of maximal heart rate (max HR). The use of a fixed percentage of these indices however, ignores other physiological or psychological aspects of human performance that may be important in attaining the desired training response. In recent years there has been heightened interest in exploring alternative methods of prescribing exercise intensity. The most promising of these appears to be prescription of exercise based on measurable increases in blood lactate which occur during exercise. The ability of the blood lactate response to exercise to predict appropriate exercise intensity more reliably than a fixed percentage of VO_2 max or max HR offers potential benefits within a variety of healthy, athletic and diseased populations (Eston & Connelly, 1996).

Disadvantages with the prescription of exercise based on blood lactate concentrations include the invasive nature of the procedure (blood samples need to

be taken from the subject), the expense of laboratory equipment required for testing and the time required to analyse results.

Subjective rating of perceived exertion (RPE) is a subjective measure of exercise intensity based on a combination of central and local sensations of effort felt by any individual during the course of exercise. Studies by Demello, Cureton, Boineau and Singh (1987) and Seip, Snead, Pierce, Stein and Weltman (1991) suggest that there is a strong relationship between RPE and the blood lactate response to exercise. This raises the possibility that individuals may be able to utilise their own sense of effort to accurately predict blood lactate concentrations which are associated with improvements in endurance fitness and in so doing easily and accurately monitor their own exercise intensity without the need for invasive procedures or expensive laboratory equipment.

Noble and Robertson (1996, p.300) state the need for research aimed at the development and validation of sub maximal laboratory performance tests using perceived exertion as the criterion variable for application in both normal and diseased populations. Prerequisites of such tests is that they be technically easy to administer as well as being low cost.

Measurement of the stability of the relationship between RPE and various blood lactate concentrations during a cycle ergometer test, may provide the basis for the

development of a simple, valid and reliable testing protocol when employing the RPE/blood lactate relationship as the basis of exercise prescription.

1.2 Research Questions

The purpose of the study is to investigate the stability of the relationship between the blood lactate response to exercise and RPE in two groups of people (high and low active). The study will aim to answer the following questions:

(1) Does a strong correlational relationship exist between RPE and blood lactate concentrations measured during incremental exercise?

(2) Do highly active individuals experience the same RPE at a given blood lactate concentration during incremental exercise as less active individuals?

(3) Do central and local perceptions of strain play the same role in the overall sense of effort at a given blood lactate concentration in highly active compared with less active individuals during incremental exercise?

1.3 Research Hypotheses

In the proposed study the following hypotheses will be tested.

Hypothesis 1. A positive correlational relationship will exist between RPE values and fixed blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol measured during incremental cycle ergometer exercise.

Hypothesis 2. There will be no significant difference in central, RPE values obtained at fixed blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol in highly active compared with less active individuals.

Hypothesis 3. There will be no significant difference in local RPE values obtained at fixed blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol in highly active compared with less active individuals.

Hypothesis 4. There will be no significant difference in overall RPE values obtained at fixed blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol in highly active compared with less active individuals.

1.4 Significance of The Study

(1) A test which can accurately predict appropriate RPE levels at which to train in relation to the blood lactate response to exercise eliminates the need for blood samples to be obtained or heart rate to be continually monitored by the subject throughout the course of a training session.

(2) Demonstration that the relationship between RPE and the blood lactate response to exercise remains stable for both high and low active individuals will indicate that RPE can be utilised to optimise training programs for both populations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Traditional Basis of Exercise Prescription

"VO_2 max has become so accepted as the criterion measure of cardiovascular fitness that most exercise programs have been designed to improve it, with intensity of exercise based on a given percentage of VO_2 max or max HR" (Weltman, 1995, p.V.). It has always been assumed that because the aerobic system is the predominate energy supplier for endurance activities that the higher the VO_2 max, the better the aerobic or endurance performance (Weltman, 1995, p.V). However, a comparison of VO_2 max and endurance performance in competitive runners suggests that this is not always the case. In some instances athletes with lower VO_2 max have been able to perform better than those with a higher VO_2 max (Longhurst & Blundell, 1986). This is due to the fact that VO_2 max refers to the **maximal** aerobic power. The intensity of exercise required to produce VO_2 max cannot be sustained for long periods of time. In the development of endurance fitness the aim is to achieve the optimal **sustainable** aerobic power.

2.2 Exercise Prescription Based on Blood Lactate Concentration

Lactate threshold (LT) is the highest intensity of exercise possible before a continuous increase in blood lactate levels and is the variable suggested to explain why some individuals with lower VO_2 max can perform better during endurance exercise than those with higher values. It has been established that an increase in the appearance of blood lactate due to imbalances in the production and removal of muscle lactate is a major limiting factor in endurance exercise and that exercise training based on various blood lactate concentrations is a more accurate predictor of endurance performance than VO_2 max in both athletes and non athletes (Stegmann & Kindermann, 1982). Blood lactate concentrations associated with improvements in endurance performance occur at exercise intensities of between 50-90% VO_2 max and so an exercise prescription based on a fixed percentage of VO_2 max will see some participants training above or below appropriate blood lactate concentrations. This can lead to ineffective training, cause a loss of motivation for the participant and, in the clinical setting, heighten the risk of a medical incident (Mahler & Horrowitz, 1994; Myers, 1994).

2.3 Appropriate Blood Lactate Concentrations

There remains debate amongst researchers as to the appropriate concentration of blood lactate measured during exercise testing which will result in an improvement in endurance performance when used as the basis of an exercise program.

Yoshida, Mamoru, Masahiko and Suda (1987) studied the relationship between four descriptors: Lactate Threshold (LT), defined as the VO_2 at which blood lactate concentration begins to rise above the resting value. LT1, defined as the point at blood lactate increases 1 mmol above the resting value. LT2, the VO_2 at which blood lactate concentration reaches a fixed value of 2.0 mmol and onset of blood lactate accumulation (OBLA), the VO_2 at which blood lactate reaches a value of 4.0 mmol were compared with aerobic capacity in untrained females. The results indicated that all of the lactate parameters were highly correlated with endurance performance. Yoshida, Suda, and Takeuchi (1982) also concluded that a training intensity corresponding to 4.0 mmol of blood lactate was effective for improvement in endurance performance. Weltman et al (1992) found that training intensities corresponding to blood lactate concentrations of 2.0 mmol and 2.5 mmol resulted in similar improvements in endurance performance while Belman and Gaesser (1991) found that 8 weeks of training at exercise intensities below LT were adequate for producing moderate gains in aerobic power. Casaburi, Storey, Sullivan and Wasserman (1994) studied the effects of training on the blood lactate response to exercise in sedentary young men and found that training intensities below LT could produce similar results to training intensities above LT when volume of training was increased.

To summarise, it appears that depending on the individual needs and training goals of participants exercise intensities associated with LT, 2.0 mmol, 2.5 mmol and 4.0

mmol blood lactate all have the potential to produce positive results when used as the basis for exercise intensity prescription.

2.4 Determinants of The Blood Lactate Response

Muscle fibre type

It appears that muscle fibre type plays an important role in lactate production in humans. Ball-Burnett, Green and Houston (1991) examined energy metabolism in type one and type two muscle fibres during one legged cycle ergometer exercise. Needle biopsy techniques were used to sample muscle tissue and it was found that higher lactate concentrations were observed in the type two fibres whilst more pronounced glycogen degradation was found in type one fibres. It was concluded that higher lactate levels in type two fibres were a result of greater anaerobic metabolism while more pronounced degradation of glycogen in the type one fibres indicated greater involvement in the activity performed. Because motor unit recruitment during exercise progresses from type one to type two fibres it appears that individuals with greater percentages of type one fibres should be able to attain higher work rates before observation of LT (Weltman, 1995, p35). Ivy, Withers, Van Handle, Elger and Costill (1980) also found a strong positive correlation between the percentage of type one fibres and LT. In reviewing this research Weltman (1995, p.37) suggested that the relationship observed between the percentage of slow twitch fibres and LT may exert a genetic influence over LT and thus may limit the ability to improve LT beyond a genetically determined upper

limit. Sjodin and Jacobs (1991) found that OBLA was positively correlated to marathon performance, percentage of type one fibres, percentage of type one fibre area, capillary density and training. In addition Tesch, Sharp and Daniels (1991, cited in Weltman, 1995, p.36) found that 92% of variance in OBLA could be explained by the percentage of type one fibre area and capillary density.

Substrate availability

There have been numerous studies conducted which show that an alteration in substrate availability has an effect on the blood lactate response to exercise. Ivy, Costill, Van Handel, Essig and Lower (1981) examined the effects of substrate on the blood lactate response to exercise by having subjects perform a progressive cycle ergometer test under three conditions: a) control, b) after ingestion of 75g of glucose and c) after elevation of free fatty acids by heparin administration. The results showed no difference between the control and glucose conditions. However LT occurred at a higher $\%VO_2$ in the heparinised condition. This suggests that substrate availability plays a role in the lactate response to exercise, although it is pointed out by Weltman (1995, p.39) that the results of the experiment were not tested against endurance performance. Hughes, Turner and Brooks (1982), compared LT in glycogen depleted and normal glycogen states. It was found that in the glycogen depleted state LT occurred at a higher work rate. The authors suggested that the possibility of glycogen depletion due to dietary factors or heavy exercise should be taken into account when individuals are tested.

Caffeine use

There is considerable debate as to the effect of caffeine on blood lactate concentration. Weltman (1995, p.41) states that LT does not appear to be affected by caffeine ingestion or withdrawal, however studies on absolute lactate levels following caffeine ingestion have produced differing results, some showing increases in blood lactate concentration and others showing decreases in lactate concentration during exercise following caffeine ingestion. Any decrease in blood lactate is probably due to increased free fatty acid utilisation and subsequent glycogen sparing following caffeine ingestion. It appears that the caffeine ingestion by subjects prior to lactate testing should be taken into account by researchers.

Training state

Endurance training decreases the blood lactate response to exercise at a given work intensity. A typical response to nine weeks of endurance training is shown in Figure 2.1. As can be seen, a period of training causes any increase in blood lactate levels as a result of increases in exercise intensity to occur at a higher workload. This effect is often termed the "shift to the right" of the lactate curve. The reason for this response is probably due to either a decreased rate of lactate production or an increased rate of lactate removal or both (MacRae, Dennis, Bosch & Noakes, 1992). A major influence on the diminished appearance of lactate is a decrease in the utilisation of carbohydrate following training (Shephard & Astrand, 1992). Coggan, Kohrt, Spina, Kirwin, Bier, and Holoszy (1992) examined the difference in carbohydrate utilisation in subjects with low LT (2.5 mmol occurring

at <50% VO_2 max) and high LT (2.5 mmol occurring >60% VO_2 max). The authors concluded that that the oxidation of carbohydrates was lower in the high LT group than in the low LT group.

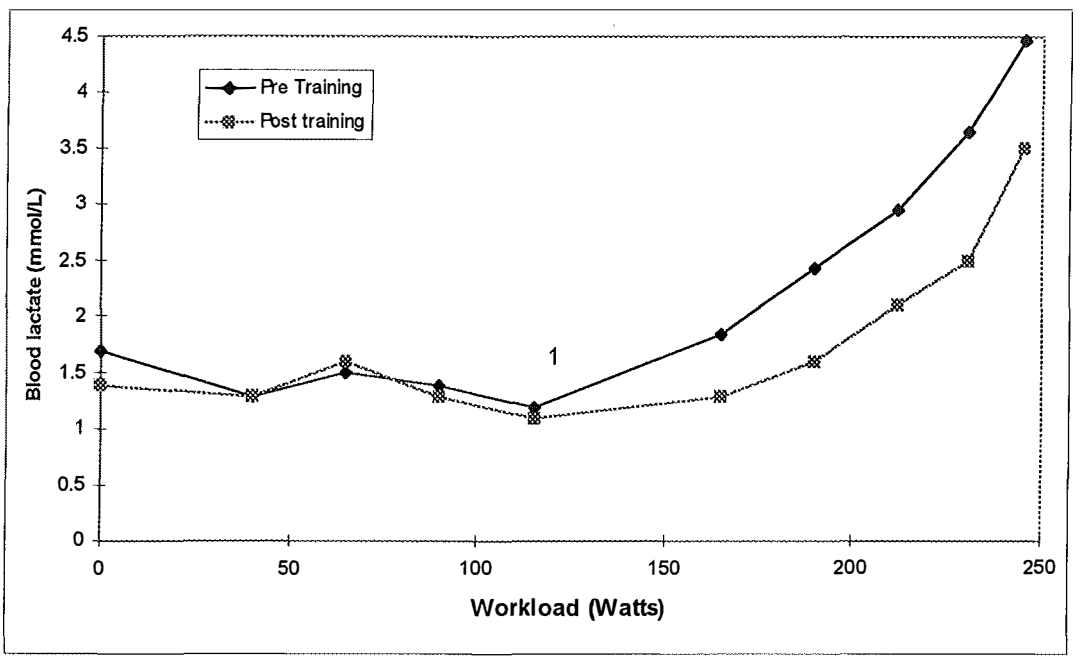

FIGURE 2.1 EFFECT OF INCREASING WORK RATE ON BLOOD LACTATE ACCUMULATION BEFORE AND AFTER TRAINING

Source: Weltman, A. (1995, p.43). The Blood Lactate Response To Exercise. Champaign. Human Kinetics.

Specificity of training

Pierce, Weltman, Seip and Snead (1990) studied the effects of specificity of training on blood lactate concentration during exercise. Sedentary males were assigned to testing protocols on both cycle and treadmill ergometers. After completion of training (four days per week for ten weeks) subjects were retested. Results showed that training improvements in LT were specific to the mode of exercise.

Environment

There are two types of environmental conditions, temperature and altitude, that appear to have an impact on the blood lactate response to exercise. Weltman (1995, p.46) states that acute exposure to altitude results in a greater blood lactate concentration at a given work rate. This effect seems to be diminished after acclimatisation takes place.

Interestingly it has been discovered that at altitude, although maximal post exercise lactate levels are higher than those observed at sea level, lactate levels are lower for the same relative exercise intensity *following acclimatisation* (Green, Sutton, Young, Cymerman & Houston, 1989). It may be the case that the balance between lactate production and removal is altered by exposure to altitude. During leg muscle exercise lactate release from the legs has been shown to increase by up to 80% following exposure to altitude (Young, 1990). However lactate uptake was

greater in the liver and inactive skeletal muscle lactate uptake was also increased during hypoxic exposure.

It has been established that when subjects are exposed to higher than normal ambient temperatures or are pre heated there is a clear decline in VO_2 max, time to exhaustion and a greater than normal increase in blood lactate concentration during prolonged exercise (Weltman, 1995, p.46). In contrast, exposure to cold conditions produces higher work intensities at LT and other blood lactate concentrations (Weltman, 1995, p.46).

2.5 Blood Lactate Testing And Interpretation

Testing Protocol

There has been considerable disagreement in the research literature as to the most appropriate protocol for conducting exercise tests measuring blood lactate concentration. This is an important point because the testing protocol employed may have a large impact on the interpretation of the results of testing (Weltman, 1995, p.31).

Hagberg (1986, cited in Weltman, 1995, p.31) suggested that a series of discontinuous 10 minute exercise bouts should be used due to the fact that endurance capacities are best determined during steady state exercise. Foxdal, Sjodin and Sjodin (1996) found that blood lactate concentrations obtained from

incremental exercise with durations of less than eight minutes failed to elicit a steady state. However Weltman, Snead, Stein, Seip, Rutt and Weltman (1990) in a study of male runners, concluded that a continuous horizontal treadmill protocol using three minute stages resulted in a reliable and valid measure of exercise intensity associated with lactate threshold as well as blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol. A three minute continuous protocol also results in a safe, convenient test (Gullstrand, Sjodin & Svendberg, 1994), especially in the clinical setting where the stresses imposed by a 10 minute workload lead to an unacceptable safety risk for participants.

Sampling site

The sampling site used for the extraction of lactate may have an influence on the recorded level of lactate and so must be considered as a determining factor in the interpretation of blood lactate testing. Foxdal, Sjodin, Rudstam, Ostman, Ostman and Hedenstierna (1990) investigated the distribution of lactate in plasma, whole blood, erythrocytes and capillary finger blood before and during sub maximal exercise in healthy male subjects. The study found that direct comparisons between lactate in capillary finger blood, venous whole blood and plasma could not be made.

Sayed, Wilkinson, Mullan, Fenoglio and Flannagsan (1993) conducted a similar study. Subjects were asked to run on a treadmill for four minute bouts of exercise. During a one minute rest between workloads a blood sample was taken from both

finger tip and mixed venous blood which was then compared for blood lactate concentration. Blood lactate concentration was significantly higher for finger tip samples than for venous blood samples obtained from the antecubital vein prior to exercise and in response to all four exercise levels. It was not possible to conclude from the study whether differences were due to lactate uptake (redistribution of lactate extravascularly and intravascularly) or the distribution of blood flow. The results indicated however that differences in the recorded lactate concentration between finger tip and venous blood do exist during treadmill exercise and should be taken into consideration when blood lactate concentration is used as the criterion to prescribe exercise intensity.

Interpretation of lactate data

The blood lactate response to exercise is usually presented in graphical form displaying lactate concentration on the Y axis and an independent variable (time, heart rate, velocity, VO_2) on the X axis. Various methods of identifying the point on the curve produced by incremental exercise at which blood lactate begins to lose steady state conditions during continuous exercise have been proposed. Jarvis (1990) suggested that LT be determined from the point at which the slope rises at an angle of 51 degrees (45 degrees for untrained individuals). MacDougall, Wenger and Green (1991, p.139) cite more precise interpretation techniques. One method utilises the curve of post exercise recovery lactates to the concentration of lactate at the completion of the testing protocol as a point for constructing a tangent to the exercise lactate curve. Another method is to establish a tangent to

the lactate curve that is parallel to the slope of a 1.0 mmol rise in lactate during three minutes of exercise

Boutcher, Seip, Hetzler, Pierce, Snead and Weltman (1989) employed a visual inspection method to determine the lactate/work relationship. This method was found to be reliable, with test-retest positive correlations of r=0.89 for work and r=0.82 for VO_2 with no significant differences in scores between tests.

2.6 Practical Limitations of Blood Lactate Testing

Despite the relevance and validity of blood lactate testing as a means to predict appropriate exercise intensity, the challenge still exists to design simple, reliable methods of assessing blood lactate concentration during testing and training.

There are two major problems in designing such methods. Firstly, even with the advent of portable lactate analysis machines, obtaining blood samples during training is expensive, time consuming and potentially hazardous due to infection risk. Secondly, evidence suggests that as training state alters and endurance capacity increases so too does LT as a function of VO_2 max. Hurley, Hagberg, Allen, Seals, Young, Cudihee and Holloszy (1984) while investigating the effects of exercise intensity on the blood lactate response to exercise reported that training

elicited a 26% increase in VO_2max. In addition, lactate concentrations at the same relative VO_2 (55%-75%) were significantly lower after training. Importantly the researchers also found that the VO_2 corresponding to LT (defined as 2.5 mmol blood lactate) increased 39% due to training. This indicates that changes in LT can occur independently of changes in VO_2 max. In other words, training at a given velocity, or heart rate prescribed as that associated with lactate threshold at the start of a training program may not be useful due to the fact that the lactate threshold itself will occur at a higher velocity or heart rate as training progresses meaning that exercise intensity must be regularly adjusted to account for training effect. In light of these problems various simple, non invasive methods of exercise prescription based on the blood lactate response to exercise have been proposed.

2.7 Non Invasive Measures of Blood Lactate

Conconi (1982) proposed an incremental protocol based on the assumption that heart rate increases linearly with workload. At higher exercise intensities it was found that the relationship between heart rate and workload displayed a loss of linearity. Data collected by Conconi suggested that this loss of linearity represented LT. The Conconi test was widely adopted because of its non invasive nature, as well as the ease with which it could be applied to the field setting. However, further research has revealed that the loss of linearity does not occur in all athletes, or that when loss of linearity does occur, it does so at blood lactate concentrations which are variable, and sometimes well above appropriate levels (Newton, 1990). In addition Harrison, Dawson, Lawrence and Blanskby (1992)

directly compared invasive versus non-invasive testing of female competitive swimmers and found that determining LT non invasively using heart rate did not correspond to the same LT established using blood lactate analysis.

An alternative method of determining LT non invasively is by observing changes in minute ventilation (VE) during an incremental exercise test (Fox, Bowers & Foss, 1989, p.209). VE increases in a linear fashion with increasing workload until LT is reached (Wilmore & Costill, 1988). At the point corresponding with LT this linearity is lost due to the increased need to buffer CO_2 associated with increased lactic acid production. The theory that the ventilatory and the blood lactate response to exercise are linked has however been challenged by several researchers in recent years. Poole and Gaesser (1985) examined the effect of interval training versus continuous training on the relationship between LT and VE in sedentary males. At the completion of eight weeks of training the group which completed continuous training elicited a far greater increase in LT than VE. The marked dissociation between the changes in the two parameters after training led the researchers to conclude that LT and VE are controlled by different mechanisms and should not be used interchangeably as indices of training adaptations. Berry, Stoneman, Weyrich and Burney (1991, cited in Weltman, 1995, p.8) examined the effect of caffeine ingestion and found that ingestion of 7mg of anhydrous caffeine also resulted in a dissociation of LT and VE, placing further doubt as to the validity of using VE to estimate LT. Finally, respiratory

measurement apparatus used in the laboratory setting is often expensive and/or inaccessible to the vast majority of the population.

Ratings of Perceived Exertion (RPE)

Rating of perceived exertion (RPE) is a subjective measure of exercise intensity based on sensations of effort felt by any individual during the course of exercise. A number of recent studies have shown a direct relationship between RPE and the blood lactate response to exercise (Weltman, 1995, p.71). This relationship appears to remain unaffected by factors such as gender (Demello, Cureton, Boineau & Singh, 1987), training state (Seip, Snead, Pierce, Stein & Weltman, 1991), type of exercise (Hetzler, Seip, Boutcher, Pierce, Snead & Weltman, 1991) specificity of training (Boutcher et al, 1989), or intensity of training (Haskvitz, Seip, Weltman, Rogol & Weltman, 1992). This raises the possibility that individuals may be able to utilise their own sense of effort to accurately predict blood lactate concentrations during an aerobic exercise session and in so doing accurately monitor exercise intensity without the need for invasive procedures or expensive laboratory equipment.

2.8 Basis Of Effort Sense Theory

Perception of subjective strain, rather than being the result of purely physical impact on the organism, can be thought of as a combination or configuration of physiological and psychological factors, both central and local in origin (Robertson, 1982). An illustration of how this configuration operates in practice as

well as how perceived strain is never purely physical is that of the person jogging with a partner around a running track. Firstly, physiological indicators of stress originate both from the heart and lungs (central) as well as the working muscles (local) while the stress of the situation itself introduces a psychological element. It can give rise to social competition, or require special motivation on the part of the subject (Borg, 1985, p.2). Figure 2.2 illustrates how the strain to which a person is exposed leads to a strain reaction which can be measured in both physiological and psychological terms. Measuring only physiological variables associated with the strain of the exercise taking place would still give no insight into what the objective strain meant to the person involved (Borg, 1985, p.2). Measurement of perceived exertion allows the strain of an activity to be judged in an individual relative context and not the absolute values of purely physical forces (Borg, 1985, p.2).

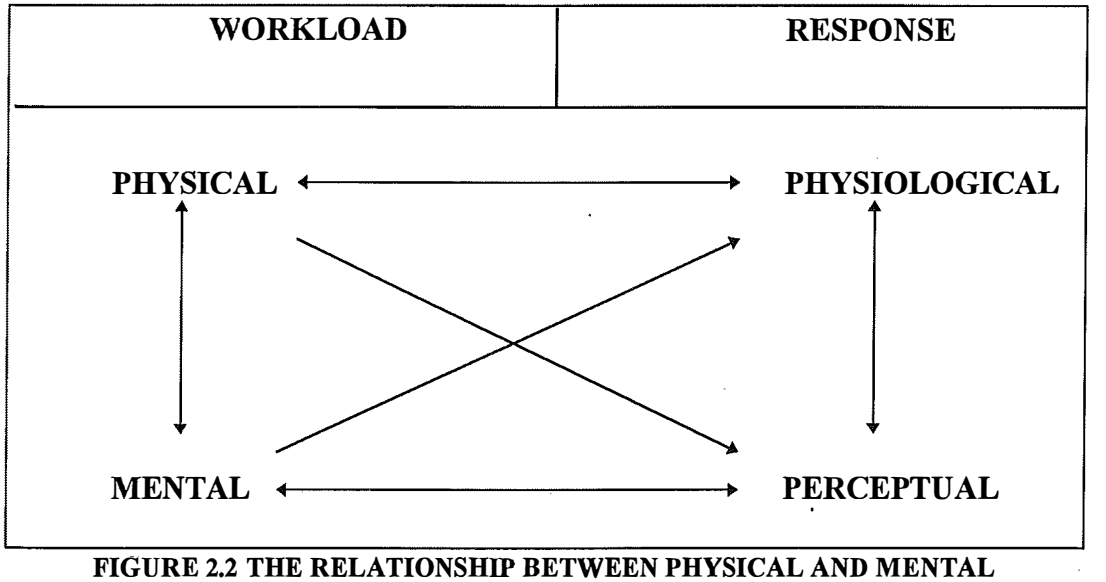

FIGURE 2.2 THE RELATIONSHIP BETWEEN PHYSICAL AND MENTAL WORKLOAD AND PHYSIOLOGICAL RESPONSE

Source: Borg,G. (1985, p.4) An Introduction To Borg's R.P.E Scale. Michigan. Mouvement Publications.

2.9 Central Determinants Of Effort Sense

Studies by Ekblom and Goldbarg (1971) and Cafarelli (1977) stated that perception of physical exertion should be evaluated on the basis of local factors involving strain on the working muscles and central factors involving the sensations of tachycardia, tachypnea and dyspnea. Central factors are believed to act as an amplifier which potentiate local signals in proportion to the aerobic metabolic demand (Robertson, 1982). The mechanism responsible for monitoring central perceptual signals is not fully understood, although it is thought that signals are discharged from either mechanoreceptors and chemoreceptors in muscles and joints or corollary responses involving central nervous system regulation and integration of a number of physiological adjustments to exercise. It was originally thought that heart rate played a major role in the central signal of effort sense. However, correlations between heart rate and RPE varied between 0.42 and 0.94, when different tasks such as treadmill walking (Skinner, Hustler, Bersteinova & Buskirk, 1973), one and two limb exercise (Gamberale, 1972) and riding a cycle ergometer (Borg, 1973) were compared. In addition Stoudemire, Wideman, Pass, McGinnes, Gaesser and Weltman (1996) observed an uncoupling of heart rate and RPE during 30 minutes of continuous exercise providing further evidence that heart rate is not a major determinant of RPE.

Robertson (1982) reviewed several studies which found that correlation coefficients of between 0.61 and 0.94 existed between RPE and $\dot{V}_E$ in neutral and

hot environments and while ascending and descending gradient during cycling. The relationship between RPE and VE appears to depend on the intensity of exercise. That is to say that exercise eliciting a minimal metabolic response will show a small influence by VE on RPE, whereas a workload of 50% VO_2 max seems to be the point at which RPE begins to parallel VE.

A number of investigators have stated that oxygen consumption (VO_2) provides the strongest contribution to central signals of exertion, with correlation coefficients between VO_2 and RPE of between 0.76 and 0.97 (Robertson, 1982). In addition it appears that relative rather than absolute VO_2 correlates most highly of all (Robertson, 1982). Eston and Connelly (1996) studied the effects of Beta blocker therapy on RPE in patients suffering cardiovascular disease, and found that although Beta blocker therapy resulted in increased local and overall RPE values that there was no difference in RPE when expressed as a percentage of VO_2 max. Hagen, Harms-Ringdall and Hallen (1994) studied the effects of lifting technique on perceptual and cardiovascular responses and found that RPE was more closely related to percent VO_2 max than to absolute VO_2 max.

In summary, it would appear that at levels of exercise not exceeding 50% VO_2 max VE plays a limited role in signalling perceived exertion while at exercise levels above 50% VO_2 max VE plays an increasingly important role in the conscious perception of effort. Recent studies suggest that relative VO_2 plays the dominant "proportional" or amplifying role at any level of exercise (Robertson, 1982).

			RELATIVE CONTRIBUTION		
		METABOLIC	CENTRAL		LOCAL
LEVEL	SYMPTOMS	INTENSITY	VE	VO_2max	
1	Movement-awareness	<50%VO_2max	Limited/Proportional		Dominant
2	Discomfort	50-70%VO_2max	Moderate/Proportional		Dominant
3	Noxious pain	>70%VO_2max	Significant/Proportional		Dominant

FIGURE 2.3 MODEL OF THE POTENTIATING RELATIONSHIP BETWEEN CENTRAL AND LOCAL SIGNALS OF EXERTION AT LOW (LEVEL 1) MEDIUM (LEVEL 2) AND HIGH (LEVEL 3) METABOLIC INTENSITY.

Source: Robertson, R. (1982). Central signals of perceived exertion during exercise .Medicine and Science in Sports and Exercise. 14,(5) 390-396.

2.10 Local Determinants Of Effort Sense

Early study of the local contribution to effort sense during exercise created, as well as answered questions. Factors associated with local RPE included electromyography (EMG), mechanoreceptors and chemoreceptors, vanilmandelic acid, catecholamines, Golgi tendon organ activity, diastolic blood pressure and anaerobic metabolites (Watt & Grove, 1993). The problem with some of the proposed local factors (Golgi tendon organs, mechanoreceptors) is that they are

virtually impossible to quantify (Pandolph, 1982). In addition catecholamines have been discredited as a local factor precursor (Gullestad, 1989, cited in Watt et al, 1993). The strongest evidence appears to support the theory that the degree of anaerobic metabolism measured as blood lactate is one of the most important determinants of local effort sense. Caffarelli (1982) found that during continuous exercise (80%VO_2 max) under conditions of induced acidosis, an extreme increase in perception of effort was not accompanied by an increase in EMG activity in the working muscles. This suggested that acidosis may be responsible in some way for the increase in sensory processes that occur during heavy exercise.

One way in which this mechanism may operate is that muscle lactate may influence local RPE by increasing intra muscular H+ concentration thus disrupting the contractile and energy producing properties of muscle leading to fatigue (Seip et al 1991). It must be pointed out however that much of the evidence lending support to the argument that lactate is responsible for local effort sense is correlational in nature (Robertson, 1982) and some researchers have challenged the notion that lactate per se is responsible for local effort sense. Allen and Pandolph (1977, cited in Robertson 1982) manipulated lactate production by asking subjects to breathe hyperoxic gas mixtures during exercise. The result was an increase in work capacity as well as a corresponding decrease in blood lactate but no change in RPE. The authors suggested that the local signal resulting may have been a combination of relative workload and blood lactate levels. Modification of local

signals of effort may occur via afferent signals from the cardiovascular and respiratory systems or from the joints and skin (Jones & Round, 1995, p.136).

2.11 Differentiated Effort Sense

The term "effort sense" often refers to a general or overall perception of effort (Borg, 1985, p.2). This is obviously a complex perception which integrates a combination of signals from both central and local regions. Kinsman and Weiser (cited in Robertson, 1982) proposed a model of perceptual responsiveness that assigned ratings to either a differentiated or undifferentiated level of sensory processing.

Robertson, Gillespie, McCarthy and Rose (1979) state that overall or undifferentiated perception of effort represents a superordinate level of effort sense not directly linked to the underlying physiological processes at work but rather a complex integration of many differentiated sensations, arising from specific physiological events. Each of these events has its own perceptual weighting based on the body region predominantly involved in a particular work task (Robertson et al, 1979). Various authors (Astrand & Rodahl, 1977; Ekblom & Goldbarg, 1977; Gamberele, 1972, cited in Robertson et al, 1979) have found that in an activity such as cycling in which the majority of the work is produced by the legs, local effort sense dominates the overall perception of effort. Pandolph (1982) reviewed literature pertaining to the differentiated sense of effort and found that in many cases local RPE values were higher than central RPE values and that quite often,

local RPE was higher than overall RPE. Robertson et al (1979) postulated that the reason for the dominance of local RPE during cycling was possibly due to a switch in attentional focus by the subject away from the relatively low level of central signals of exertion originating in the chest to the more intense local discomfort occurring in the legs. In addition Robertson et al (1979) found that during cycling, overall RPE values approximated the mean of the central and local values at all workloads. Pandolph (1982) however, states that when pronounced regional feedback originates from two sources as is the case when running, the undifferentiated perception forms a gestalt which is set higher than either differentiated signal. Carton and Rhodes (1985) suggest that there exists a critical work threshold which must be achieved before central sensations of effort significantly effect the perception of effort

2.12 Psychological Determinants Of Effort Sense

So far in this paper the physiological components of effort sense have been discussed. As suggested by Borg (1973) RPE is best viewed as a blend of sensory input made up of both physiological and psychological traits as well as a subject's past experiences. Individual differences in RPE are associated with selected psychological traits (Demello et al, 1987). Morgan (1994) investigated this area and found that extroverted subjects consistently perceived effort to be less stressful than introverts. In addition it was found that 90% of individuals were capable of accurately sensing the intensity of an exercise stimulus. Of those individuals that were not, most were found to be anxious, neurotic or depressed (Mahler, 1994).

Another psychological construct relevant to the perception of effort is that of self presentation. This theory states that in social situations individuals typically attempt to present themselves in a socially desirable way (Watt & Grove, 1993). The authors cite a study conducted by Hardy et al (1986) in which the researcher gave non verbal signs of low or high intensity to the subject. When low intensity cues were given by the researcher there was a corresponding fall in reported RPE values. The results of this study clearly demonstrate the care which must be taken when conducting studies of this nature not to compromise the integrity of results by inadvertently "coercing" the subject into falsely rating RPE values.

2.13 Other Factors Affecting Effort Sense

Age

The effectiveness of RPE in the prescription of exercise intensity does not appear to be affected by age. Although no studies directly comparing effort sense in children and adults could be found, Williams, Eston and Stretch (1991) found that no significant difference existed in RPE values as a result of age in a study involving 11 to 14 year old boys and girls. A further study conducted by Eston and Williams (1990) involving males aged between 21 and 62 found that although there were significant differences in RPE values that none of the differences were accounted for by age.

Gender

The studies previously discussed (Williams et al, 1991; Eston et al, 1990.) also examined the effect that gender may have on perceived exertion. Both experiments found no evidence of an effect on RPE by gender. In contrast Miller, Bell, Collis and Hoshizaki (1985 cited in Watt & Grove, 1993) did report a difference in gender although this difference was related to the relationship between heart rate and RPE rather than RPE alone.

Familiarisation and Previous Experience With Rating Scales

Carton and Rhodes (1985) cite a study by Hogan and Fleishman (1979) in which it was concluded that a high reliability and validity existed for perceived effort ratings independent of previous rating experience of the sample group. In addition Carton and Rhodes (1985) cite a study conducted by Stamford (1976) in which subjects were asked to rate one of four work tasks (walking, treadmill running, cycling and stool stepping) on four separate occasions. Using this procedure, RPE using the Borg 15 point scale proved to be reproducible at various intensities of the same mode of exercise irrespective of prior experience with rating scales.

Training State

Carton and Rhodes (1985) cite several studies in which it has been shown that fit and unfit subjects rate the effort required to perform standard workloads equally. Characteristic of all of the investigations reviewed by Carton and Rhodes however

is that they evaluated differences in low to moderate absolute workloads. They state that differences in RPE as a consequence of training may only be manifested during intense physical activity.

Time of day

Trine and Morgan (1995) reviewed the influence on psychological responses of exercise performed at different times of the day. The authors reported the possibility of a circadian rhythm in global effort sense following a study in which subjects participated in treadmill running in morning and afternoon sessions. This relationship however was difficult to quantify and has produced conflicting results (Trine & Morgan, 1995). The authors concluded that differences in exercise mode, RPE instructions, gender, workloads and pedalling frequencies in concert with different times of day account for an absence of consistency in the research literature.

2.14 Development Of Rating Scales

The need to be able to quantify perception of effort led to the development of a number of "tools" with which to measure perceived exertion. The first generation of these consisted of *ratio scales*, the methods of which had the same metric qualities as methods used in physiology (Borg, 1982). Tests consisted of each subject assigning a number to a given level of exertion during a task. The tests provided good general power functions for a group of subjects but because subjects were asked only to make relative comparisons, inter-individual

comparisons were difficult. For example one subject may rate an activity as number "10" on a scale whereas another subject may rate the same activity as "25". However this does not mean that the second subject *perceives* it to be heavier than the first subject.

In order to overcome difficulties associated with ratio scaling methods Borg developed the 15 point *category rating scale* (Table 2.1) in which verbal anchors make the metric (numerical) properties less important. Consequently when a subject states that a given level of exertion is "moderate", it can be assumed with some safety that the subject is talking in relative rather than absolute terms. The Borg scale consists of a 15 point category scale covering the total range of perception from extremely light exercise to extremely hard exercise. Numbers from six to twenty are used to correspond with heart rate variations from 60 to 200 beats per minute. Verbal anchors are placed at various positions on the scale in positions such that a linear increase is obtained with the power of, turning the RPE scale into a kind of equidistant interval scale (Cafarelli, 1982).

TABLE 2.1 THE BORG 15 POINT SCALE FOR RATINGS OF PERCEIVED EXERTION, THE RPE SCALE

Score	Subjective Rating
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	

Source: Borg, G. (1985, p.26). An Introduction To Borg's RPE Scale. Michigan. Mouvement Publications

2.15 RPE Testing Guidelines

When employing RPE during exercise testing Dunbar et al (1992) suggest that the following guidelines for obtaining RPE should be followed. Firstly, the patient should be familiarised with the RPE scale. Standardised instructions indicating how the subject is to communicate RPE should be used for this purpose. This process involves verbally anchoring the patient, by telling them, for example, that

six is equal to quiet sitting. This is particularly important if it is the subjects first exposure to the rating scale. RPE should be obtained at every stage of the test. A copy of the scale should remain in full view of the subject at all times. The subject should be asked to give a numerical rating. Hand signals suffice if metabolic data are being collected and verbal communication is not practical. Parfitt and Eston (1995) state that RPE values should be recorded during steady state conditions and that it may take 3-4 minutes to achieve this. Values taken before this time may be artificially low. An RPE of 18-19 usually represents maximum effort. Production of exercise intensities is usually more accurate when estimation tests are performed on a cycle ergometer (Dunbar et al, 1993).

2.16 Exercise Prescription Using RPE

Gutman, Squires, Pollock, Foster, and Anholm (1981) investigated the validity of using RPE to control exercise intensity during training. In the study 20 subjects trained for eight weeks at intensities based on RPE data gathered during a graded stress test. The results suggested that RPE can be used successfully to control exercise intensity. However Noble (1982) pointed out that subjects were not asked to produce a specific RPE but to perform at a given heart rate from which the RPE comparisons were made. Dunbar et al (1992) investigated the ability of subjects to produce exercise intensities based on RPE values estimated from trials using cycle ergometer and treadmill exercise tests. It was found that reproducability was excellent on both types of ergometers. In addition a study conducted by Robertson, et al (1990), using three different exercise modes (treadmill, cycle

ergometer, bench stepping) found that cross modal prescription of exercise intensity based on RPE is possible providing that the physiological reference point is the relative not the absolute VO_2. This was also found to be the case when comparison of males and females to effort sense were made (Noble, 1982).

2.17 Role of RPE in Exercise Based on Lactate Threshold

A number of recent studies have shown a direct relationship between RPE and the blood lactate response to exercise (Weltman, 1995, p.71). This relationship appears to remain unaffected by factors such as gender (Demello et al, 1987), training state (Seip et al, 1991), type of exercise (Hetzler et al, 1991) specificity of training (Boutcher et al, 1989) or intensity of training (Haskvitz et al, 1992). Demello et al, (1987) investigated the influence of gender on RPE corresponding to LT in male and female trained distance runners and male and female untrained subjects. The researchers found no significant difference in RPE at LT for each of the four groups despite the fact that RPE ratings were given at varying VE, $\%VO_2$ max and HR.

Seip et al (1991) studied the effect of training state on the RPE obtained at the LT and blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol. Trained runners and novice runners completed a progressive, horizontal treadmill running protocol which allowed identification of LT and various blood lactate concentrations. Despite relative and absolute physiological differences there were

no differences between groups for central, local or overall ratings of perceived exertion at any condition.

Hetzler et al, (1991) examined the effect of exercise modality on RPE and LT, and blood lactate concentrations of 2.0 mmol, 2.5 mmol, and 4.0 mmol in untrained male subjects who completed counterbalanced exercise protocols on a cycle ergometer and treadmill. A repeated measures ANOVA revealed that once again despite relative and absolute physiological differences no differences were observed in RPE at LT and blood lactate concentrations across exercise modality.

Boutcher et al (1989) investigated the effect of specificity of training on RPE at LT. College men were trained for 10 weeks (run training, cycle training, controls). Pre and post training variables were measured during graded exercise tests using both cycle and treadmill ergometers. No differences for RPE at LT were found for any group pre or post training or between testing protocols for any group.

Haskvitz et al, (1992) examined the effects of intensity of training on RPE at LT and blood lactate concentrations of 2.0 mmol, 2.5 mmol and 4.0 mmol. in untrained women. Subjects were grouped for training at LT, above LT or as sedentary controls and completed one year of run training. The researchers concluded that RPE remains stable at LT and blood lactate concentrations regardless of changes in fitness or training intensity. Studies suggest that a perceived exertion rating of 11 to 12 corresponds with LT. A rate of perceived

exertion of approximately 14 is associated with a blood lactate concentration of 2 0 mmol. A rate of perceived exertion of 14 to 15 is related to 2.5 mmol, while a rate of perceived exertion of 16 to 17 is associated with 4.0 mmol blood lactate (Seip et al, 1991).

Steed, Gaesser and Weltman (1994) examined the effects of prolonged exercise on the relationship between RPE and LT. Subjects completed 3 x 30 minute runs which produced no significant difference between RPE and blood lactate concentrations between minute 10 and minute 30. In addition Stoudemire et al (1996) examined whether overall RPE estimated during an incremental treadmill protocol could be used to produce target blood lactate of 2.5 mmol and 4.0 mmol during a 30 minute treadmill run at a constant RPE. Subjects were able to produce a stable 4.0 mmol blood lactate during the 30 minute run at RPE corresponding to 4.0 mmol blood lactate recorded during the treadmill test protocol. The authors concluded that RPE was a valid tool for prescribing exercise intensity based on the blood lactate response to exercise when the absolute RPE value, rather than the workload associated with an estimated RPE value is used to produce exercise intensity.

2.18 Summary

There is great support for the use of lactate threshold and fixed blood lactate concentrations as the basis of exercise prescription. It has been shown that the blood lactate response to exercise may be a more reliable indicator of endurance

performance than current methods, and that improvements in endurance performance by training at given blood lactate concentrations can occur independently of improvements in VO_2 max. There is still disagreement as to the most appropriate testing and prescription methods to adopt, however, it appears that the relationship between RPE and the blood lactate response to exercise may have particular relevance for exercise testing and prescription in healthy, athletic as well as diseased populations where safe, reliable, convenient testing, resulting in optimal exercise prescription is vital.

CHAPTER THREE

METHODOLOGY

3.1 Design

A two x three mixed design (Kinnear & Gray, 1994, p.139) was used to investigate the effect of three independent variables (three different blood lactate concentrations) on RPE values of two groups of subjects (high active and low active).

3.2 Subjects

The subjects for the study consisted of 20 volunteers (10 males and 10 females). The protocol for the study was approved by the ethics committee of Edith Cowan University. The subjects were drawn from staff and students of the university and colleagues of the researcher. Any subject over the age of thirty five was asked to gain a medical clearance before entry into the study was permitted. All subjects were asked to complete a health risk questionnaire (Appendix A) and sign a written consent form (Appendix B). All subjects received a written handout explaining the proposed research (Appendix B). Confidentiality was maintained by assigning each subject a number.

Subjects were allocated to one of two groups, high active (HA) or low active (LA) based on results obtained from an activity questionnaire utilising an activity index

scoring system (Appendix C). In order to meet the criteria of the HA group, subjects needed a score of 80 or above. In practical terms this meant that HA subjects had to engage in regular physical activity on more than three occasions per week, at an intensity which elicited at least intermittent heavy breathing and perspiration for a minimum of 30 minutes on each occasion. In order to satisfy requirements of the LA group subjects needed a score of 40 or below representing physical activity on less than three occasions per week, at moderate intensity or less for a maximum of 20 to 30 minutes on each occasion. Subjects in each group were matched for age, gender, body mass and body mass index (BMI). Body mass index was defined as Body mass/Height^2. Physical characteristics of the two groups are presented in Appendix D. Maximal oxygen uptake (VO_2 max) was estimated using an adjusted nomogram for calculation of maximal oxygen uptake (Astrand & Rodahl, 1986, p.365)(Appendix E).

3.3 Equipment

The cycle ergometer used for the study was a Monark 829E. This ergometer is electronically controlled to ensure accurate workload production and was calibrated prior to each testing session. A Polar PE 4000 Sportstester heart rate monitor was used to measure heart rate. Height and weight were measured using a SECA height meter and SECA weighing scales.

Blood lactate concentrations were measured using a Boehringer Mannheim Accusport portable lactate analyser. The Accusport was tested by a laboratory

technician prior to the study and was found to provide consistent results with those obtained using an Analox lactate analyser. (Further details of the Accusport appear in Appendix F). A 20 microlitre sample of capillary blood drawn from the index finger, into a modified refletron 30 microlitre heparinised capillary tube was used for lactate analysis. This method of blood sampling is currently employed by the Western Australian Institute of Sport (WAIS)(S Lawrence, personal communication, April 1996) as well as the New South Wales Academy of Sport (T Graham, personal communication, April 1996) who considered this method to be valid and reliable when used under laboratory conditions. Blood samples were taken in line with American College of Sports Medicine safety guidelines (Appendix G). Central, local and overall RPE were measured using the Borg 15 point rating scale. Data was recorded on a data collection sheet. (Appendix H).

3.4 Data Collection

The study was conducted in the exercise physiology laboratory at Edith Cowan University Joondalup, data collection taking place over a five week period in July and August, 1996. Ambient temperature in the laboratory was consistently measured between 18-22 degrees Celsius. Relative humidity was consistently measured between 50-60%. Testing was completed at various times of the day to suit subject's time schedule. Test re-test reliability was assessed using a sample of six subjects who were tested twice, at the same time of day one week apart in identical fashion.

3.5 Exercise Protocol

Equipment Preparation

The Monark 829 E cycle ergometer was attached to the mains power supply and the desired cadence (70 RPM) and workload selected. Prior to each testing session the pendulum of the cycle ergometer was calibrated using a 4kg weight. The Accusport lactate analyser was calibrated prior to every testing session using a coded calibration test strip (Appendix F). A Borg 15 point RPE scale was placed approximately three metres in front of the ergometer slightly below sitting eye level.

Subject Preparation

Upon arrival at the laboratory subjects were questioned regarding exercise levels and diet in the 48 hours prior to testing. The subject's height and weight were recorded. Subjects were then fitted with a Polar PE 4000 heart rate monitor and were asked to mount the ergometer and seat height and handle bars were adjusted accordingly.

Instructions to Participants

Instructions were issued pertaining to the procedure which was to follow, how to maintain a given workload using a metronome located on the front panel of the ergometer, and how to gauge central, local and overall RPE levels. A standard set of instructions based on those suggested by Borg (1985) was used for this purpose. Subjects were advised that an RPE of six represented minimal work as might be experienced when sitting quietly on the cycle ergometer. An RPE of 8-9 represented a workload similar to, perhaps, slow walking. 10-12 would represent an effort equivalent to a brisk walk or a light jog. 13-15 represented a level of effort similar to, perhaps a moderate run. That is to say that that although the workload feels reasonably difficult, it can still be maintained for some time. 16-18 should represent a workload that is quite hard such that it could not be maintained for an extended period of time. 18-20 represent maximal effort levels (as hard as can be imagined) that cannot be maintained for any more than a very short time. It was then explained to subjects that central RPE referred to feelings of exertion coming from the chest area i.e.heart and lungs, and that local RPE referred to feelings of exertion coming from the legs. It was stressed to participants that they should take their time and be honest and attempt to appraise RPE as correctly as possible. Subjects were asked to communicate RPE verbally by calling the number associated with the correct RPE. (A standard set of instructions is presented in Appendix I). Resting values were obtained for heart rate and blood lactate and baseline central, local and overall RPE values were recorded

Exercise Protocol

The exercise protocol consisted of a sub maximal incremental test which was chosen for safety reasons and to minimise subject discomfort associated with maximal testing. Parfitt and Eston (1995) found sub maximal testing to be appropriate for this type of study. Each subject was asked to commence exercise at an initial workload of 40 Watts. Workload was increased every four minutes by 25 Watts. Blood lactate was measured during the final 30 seconds of each workload. Heart rate as well as central, local and overall RPE were recorded during the final 15 seconds of each workload. Measurements were taken in an identical fashion at the completion of each workload until a blood lactate concentration of more than 4.0 mmol was recorded or the subject could not complete a workload.

NB. In order to limit the duration of tests to 30 minutes or less the initial workload was set at 90 Watts and the initial increment in workload set at 50 Watts for some members of the HA group at the discretion of the researcher based on knowledge of the subjects fitness level.

3.6 Data Analysis

All recorded data was entered into Excel 5.0 spreadsheet. Data was then displayed in graphical form for each subject separately. Values for blood lactate were displayed on the X axis. Values for central, local, overall RPE, and heart rate were displayed on the Y axis. The graphs were then visually inspected by the researcher and values for central, local, overall RPE, and heart rate corresponding to 2.0, 2.5 and 4.0 mmol blood lactate were recorded by dropping a perpendicular from the point through which the blood lactate concentration curve passed through 2.0, 2.5 and 4.0 mmol respectively, as described in Williams and Eston (1989). On separate graphs values for workload were displayed on the X axis. Values for blood lactate were displayed on the Y axis. The graphs were again visually inspected by the researcher and values for workload corresponding to 2.0, 2.5 and 4.0 mmol blood lactate were recorded (Figure 3.1). Visual inspection was employed by Boutcher et al (1989) and was shown to be reliable when carried out carefully. Rate of lactate increase was represented by the increase in lactate measured during the workload in which a 4.0 mmol blood lactate concentration was observed. The information gathered from the procedures described above was used to produce the descriptive statistics for the study.

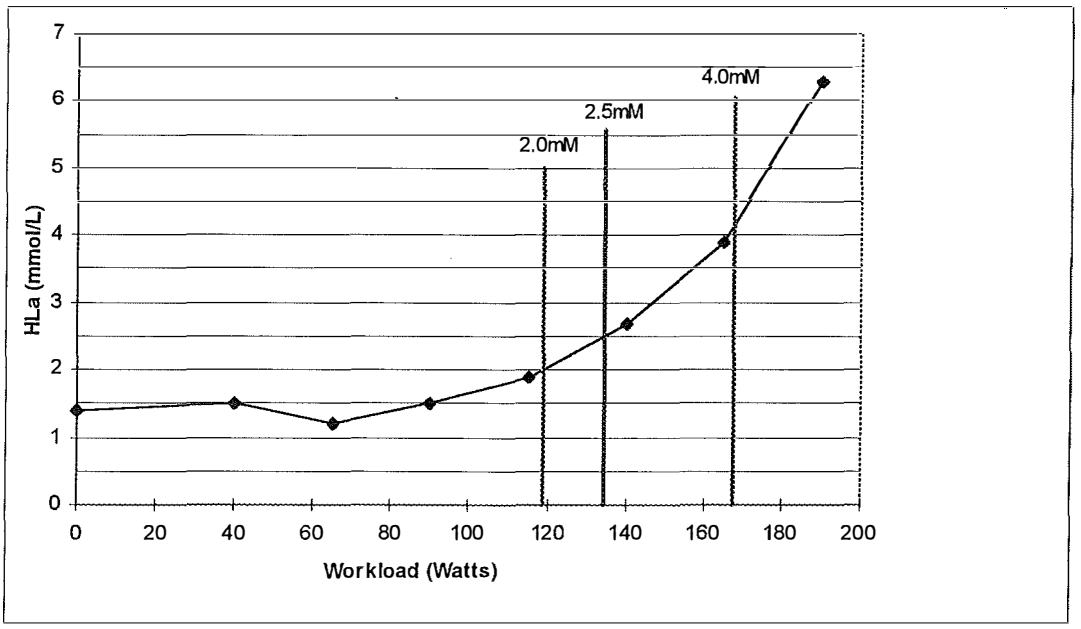

FIGURE 3.1 TYPICAL DATA ANALYSIS PROCEDURE USED TO IDENTIFY VALUES CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE

3.7 Statistics

Statistical analysis was performed using Edstats statistical package and SPSS for Windows statistical package. A significance level of 0.05 was set in line with previous studies of this nature.

A 2 (groups) x 3 (blood lactate concentrations) mixed ANOVA was performed in order to identify any significant differences between the two experimental groups for central, local and overall RPE, heart rate and workload corresponding to 2.0, 2.5 and 4.0 mmol blood lactate. The independent groups t-test was used post hoc on any variable where significant differences were revealed by the ANOVA analysis. The independent groups t-test was also used to determine if there was a significant difference between the means of the two groups for reported activity levels, estimated VO_2 max and rate of lactate appearance. Pearson r product moment correlation was used to test the strength of the relationship between

central, local and overall RPE and blood lactate concentrations of 2.0, 2.5 and 4.0 mmol.

A two tailed analysis was used due to the fact that subjects in a given group could rate sensation of effort as higher or lower at a given blood lactate concentration.

3.8 Limitations

The very definition of effort sense implies that despite the use of standardised instructions to participants on how to rate feelings of strain the researcher is presented with a *subjective* evaluation by the subject as to the intensity of activity being performed which may be influenced by psychological factors previously discussed.

Food intake of the subjects was not monitored. All subjects were asked to consume their normal food intake the day before each testing session in order to maintain similar nutrient stores (in particular, glycogen levels). (Appendix B)

Exercise external to that involved in testing was not monitored. Subjects were asked to refrain from moderate or intense exercise 24 hours prior to testing. (Appendix B)

3.9 Assumptions

It was assumed that subjects followed the procedure set down during recruitment pertaining to food intake and exercise 48 hours prior to participation in the study.

CHAPTER 4

RESULTS

Tabulated results appear in Appendix J. Raw data and statistical tests appear in full in Appendix K. Full test-retest results appear in Appendix L. Group means are presented in text ± standard error of the mean (SEM).

4.1 Reliability

Six subjects (3 HA and 3 LA) were asked to complete a second test in order to assess the reliability of the protocol. The tests were performed at the same time of day one week apart in an identical fashion. Coefficient of variation (V) was below 4% for all relevant variables at the 2.5 and 4.0 mmol conditions, with the exception of overall RPE corresponding to 2.5 mmol blood lactate for which V was 7%. Test/retest reliability data for workload, heart rate, central, local and overall RPE is presented in Table 4.1. Test/retest data in full including calculations is presented in appendix L.

Table 4.1

Test/Retest reliability data for workload, heart rate, central, local and overall RPE.

Variable	ME	V (%)
Workload (Watts) at 2.0 mmol blood lactate	12.39	12.20
Workload (Watts) at 2.5 mmol blood lactate	3.14	2.60
Workload (Watts) at 4.0 mmol blood lactate	2.34	1.50
Heart Rate (BPM) at 2.0 mmol blood lactate	4.89	4.40
Heart Rate (BPM) at 2.5 mmol blood lactate	4.68	3.90
Heart Rate (BPM) at 4.0 mmol blood lactate	4.32	3.10
Central RPE at 2.0 mmol blood lactate	1.03	9.80
Central RPE at 2.5 mmol blood lactate	0.39	3.30
Central RPE at 4.0 mmol blood lactate	0.38	2.70
Local RPE at 2.0 mmol blood lactate	1.17	10.40
Local RPE at 2.5 mmol blood lactate	0.46	3.90
Local RPE at 4.0 mmol blood lactate	0.32	2.03
Overall RPE at 2.0 mmol blood lactate	1.13	10.60
Overall RPE at 2.5 mmol blood lactate	0.84	7.00
Overall RPE at 4.0 mmol blood lactate	0.39	2.50

ME = Method Error, V = Coefficient of Variation.

4.2 Activity Questionnaire

There was a substantial difference between HA and LA for scores obtained from the Activity Index questionnaire used by the researcher to separate the two experimental groups on the basis of regular participation in physical activity. An Independent t-test revealed that the difference between the groups was highly significant ($p<0.01$). Mean activity index score was 88 ± 3.27 for HA and 29.6 ± 2.80 for LA (Figure 4.1).

4.3 Estimated VO_2 max

Mean estimated VO_2 max for HA and LA are presented in Figure 4.2. Mean estimated VO_2 max (ml/kg/min) was 20% higher for HA (52.91 ± 3.81 ml/kg/min) than for LA (42.97 ± 3.41 ml/kg/min). An independent groups t-test revealed that although the difference between the groups was large it was not statistically significant ($p=0.07$). VO_2 max for HA placed that group in the 85th percentile for the Australian population. Mean VO_2 max for LA placed that group in the 30th percentile for the Australian population. (Gore & Edwards, 1992, p.34)(refer Appendix M).

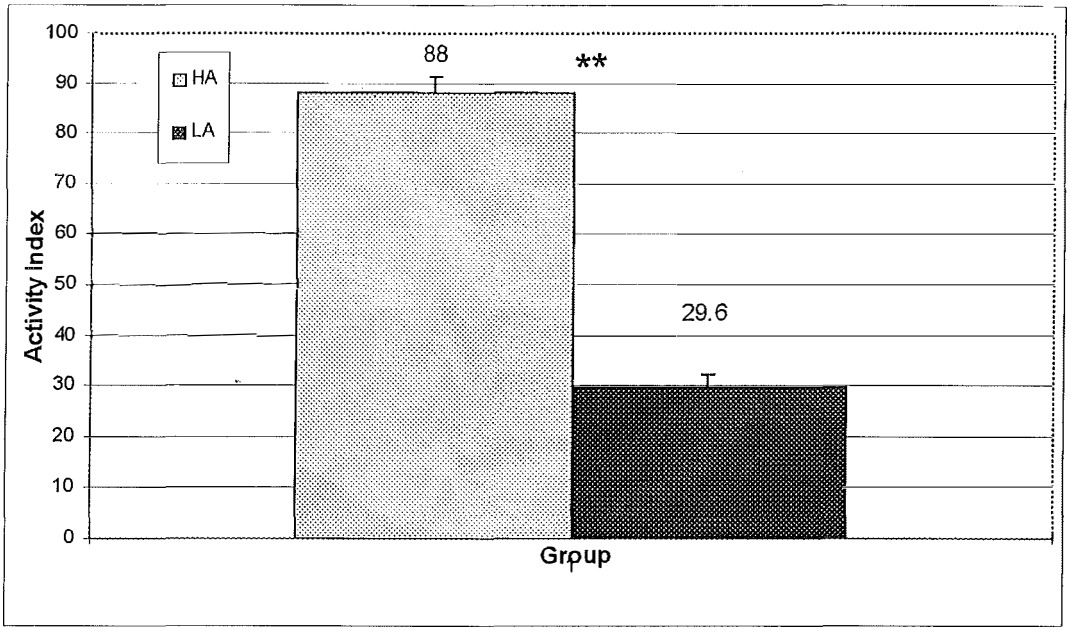

FIGURE 4.1 ACTIVITY QUESTIONNAIRE RESULTS. (MEANS ± SEM)

** Denotes significant differences at the level of 0.01 between groups.

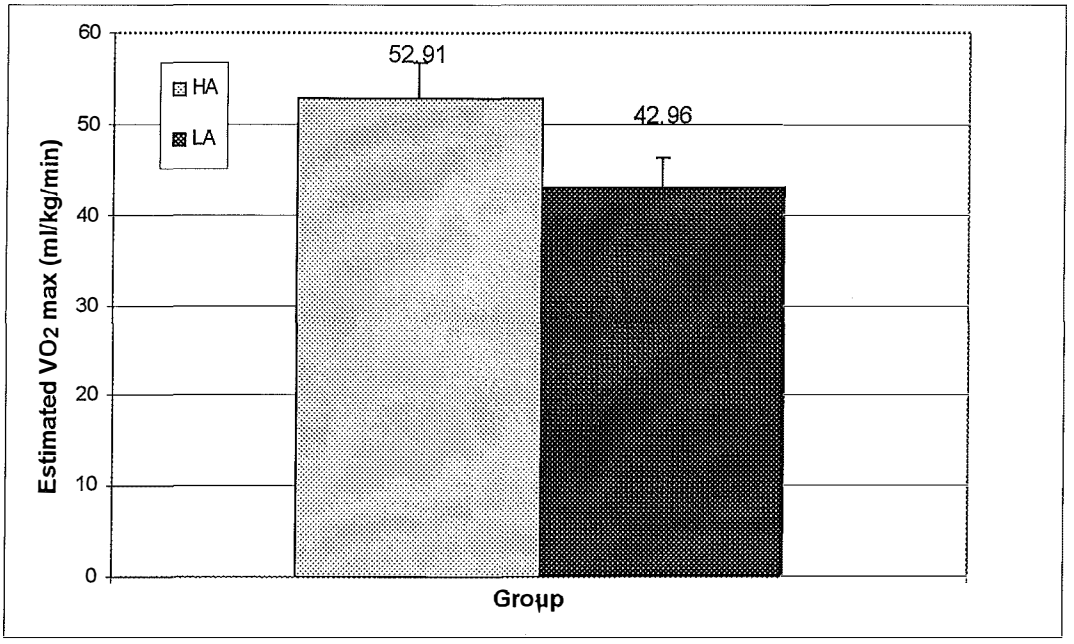

FIGURE 4.2 ESTIMATED VO_2max (ML/KG/MIN) (MEANS ± SEM)

4.4 Workload

Mean workload corresponding to 2.0, 2.5 and 4.0 mmol blood lactate are presented in Figure 4.3. A considerably higher workload (approximately 40%) was required to produce each of the three blood lactate conditions in HA than in LA. Mean workload corresponding to 2.0 mmol blood lactate was 106.2 ± 13.4 watts for HA and 55.8 ± 10.37 watts for LA. Workload corresponding to 2.5 mmol blood lactate was 136.2 ± 19.22 watts for HA and 78.8 ± 9.85 watts for LA. Workload corresponding to 4.0 mmol blood lactate was 178.5 ± 21.2 watts for HA and 113.7 ± 11.7 watts for LA. ANOVA analysis revealed these differences to be highly significant ($p<0.01$). Independent t-tests revealed the difference at 2.0 mmol ($p<0.01$) to be highly significant and at 2.5 mmol and 4.0 mmol ($p=0.02$) to be significant.

4.5 Heart Rate

Mean heart rates corresponding to 2.0, 2.5 and 4.0 mmol blood lactate are presented in Figure 4.4. Heart rate (BPM) corresponding to each of the blood lactate conditions was consistently lower (approximately 10%) for LA than for HA. ANOVA revealed these differences to be highly statistically significant ($p=0.01$). Independent t-tests confirmed significant differences between groups at the 2.5 mmol condition ($p=0.02$) and highly significant differences at the 4.0 mmol condition ($p=0.002$) where mean heart rate was 156.4 ± 2.37 for HA and 142.9 ± 2.93 for LA. Mean heart rate corresponding to 4.0 mmol blood lactate occurred at 80% and 73% age predicted maximum for HA and LA respectively.

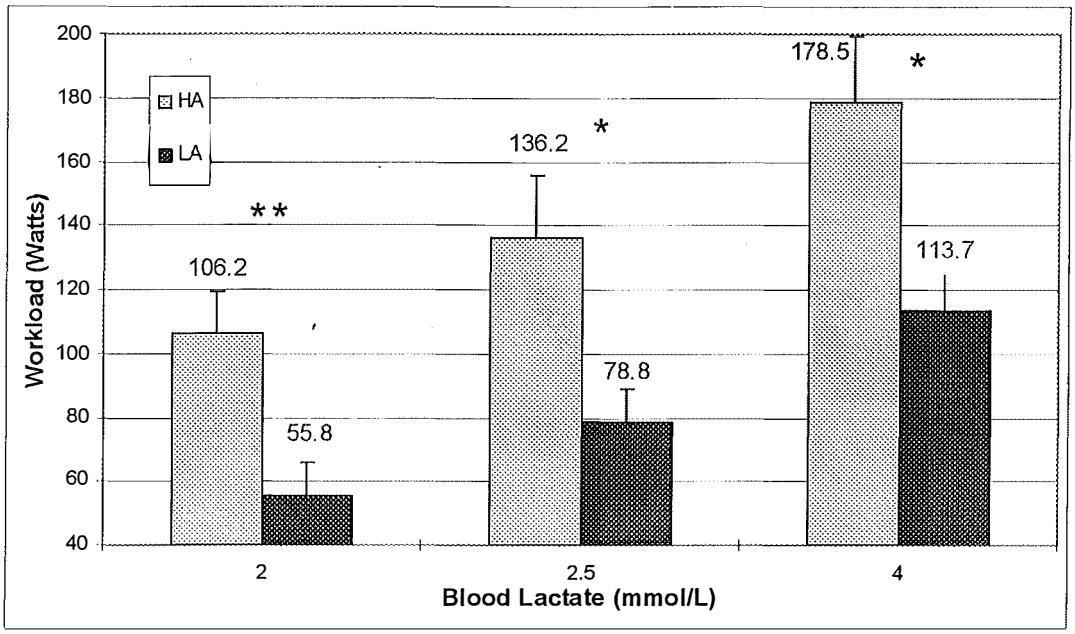

FIGURE 4.3 WORKLOAD (WATTS) CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

* Denotes significant difference at the level of 0.05 between groups.

** Denotes significant differences at the level of 0.01 between groups.

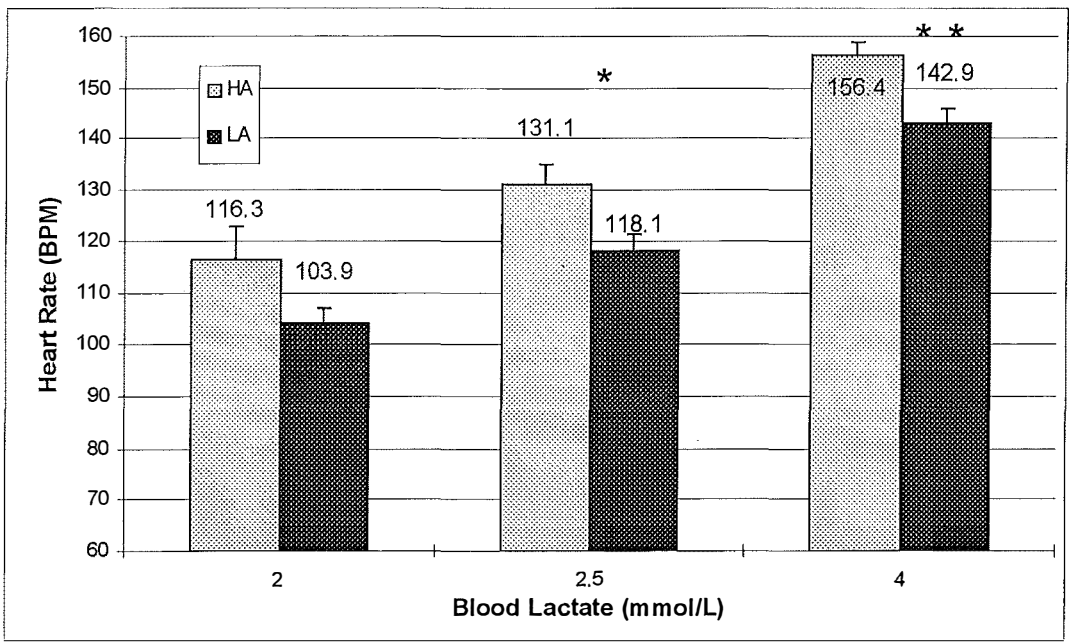

FIGURE 4.4 HEART RATE (BPM) CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

* Denotes significant difference at the level of 0.05 between groups.

** Denotes significant differences at the level of 0.01 between groups.

4.6 Rate of Lactate Appearance

The rate of blood lactate appearance was 1.66 ± 0.20 mmol per 25 watt workload for HA and 1.46 ± 0.10 mmol for LA at the workload during which to 4.0 mmol blood lactate was elicited. This represented a difference between the groups of some 12%. An independent groups t-test revealed the differences between groups to be non significant (p=0.08).

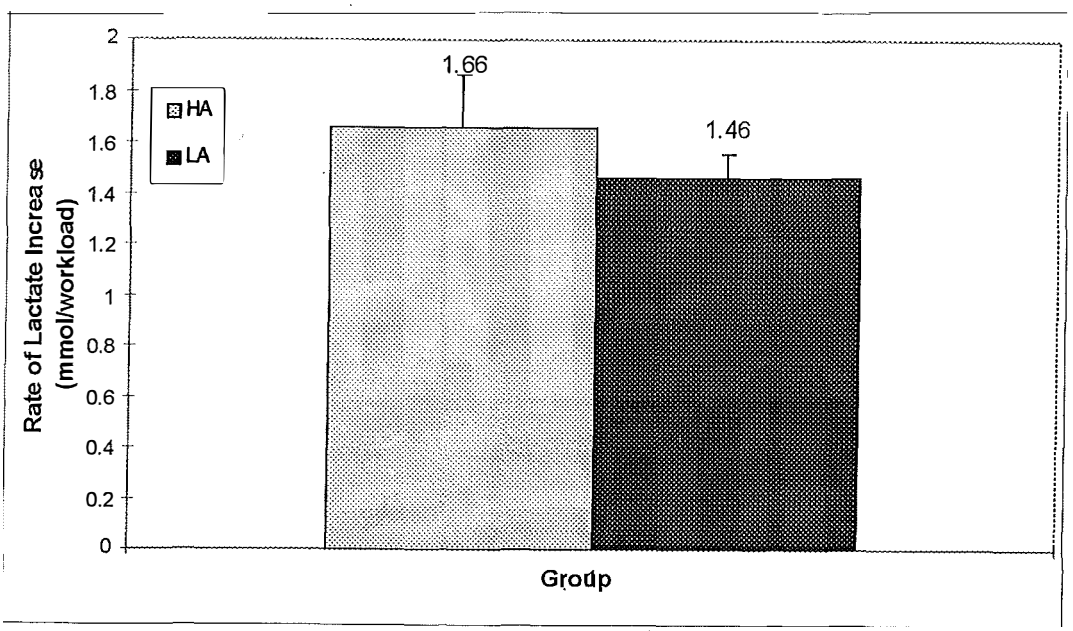

FIGURE 4.5 RATE OF LACTATE APPEARANCE (mmol/25 WATT WORKLOAD) AT THE WORKLOAD CORRESPONDING TO 4.0 mmol BLOOD LACTATE. (MEANS ± SEM).

4.7 Relationship Between blood lactate and RPE

Group mean central, local and overall RPE values corresponding to 2.0, 2.5 and 4.0 mmol blood lactate are presented in Figure 4.6. Mean overall RPE corresponding to 2.0, 2.5 and 4.0 mmol blood lactate were 9.8, 11.5 and 15.3 respectively. Pearson r product moment correlation tests were used in order to test the strength of the underlying relationship between central, local and overall RPE values corresponding to 2.0, 2.5 and 4.0 mmol blood lactate (Figure 4.7). A highly significant positive correlation ($p<.001$) was revealed for central, local and overall RPE values at each of the blood lactate conditions examined during this study when the means of both groups were combined. Correlation coefficient for central RPE was 0.74. Correlation coefficient for local RPE was 0.73 while correlation coefficient for overall RPE was 0.72.

In addition for all blood lactate conditions local RPE was rated highest by subjects followed by overall RPE with central RPE rated lowest at each blood lactate condition (both groups combined). An uncoupling of central and local RPE became apparent as exercise intensity and blood lactate concentration increased in absolute terms. The difference between local and central RPE in relative terms remained stable at all blood lactate conditions at approximately 10%.

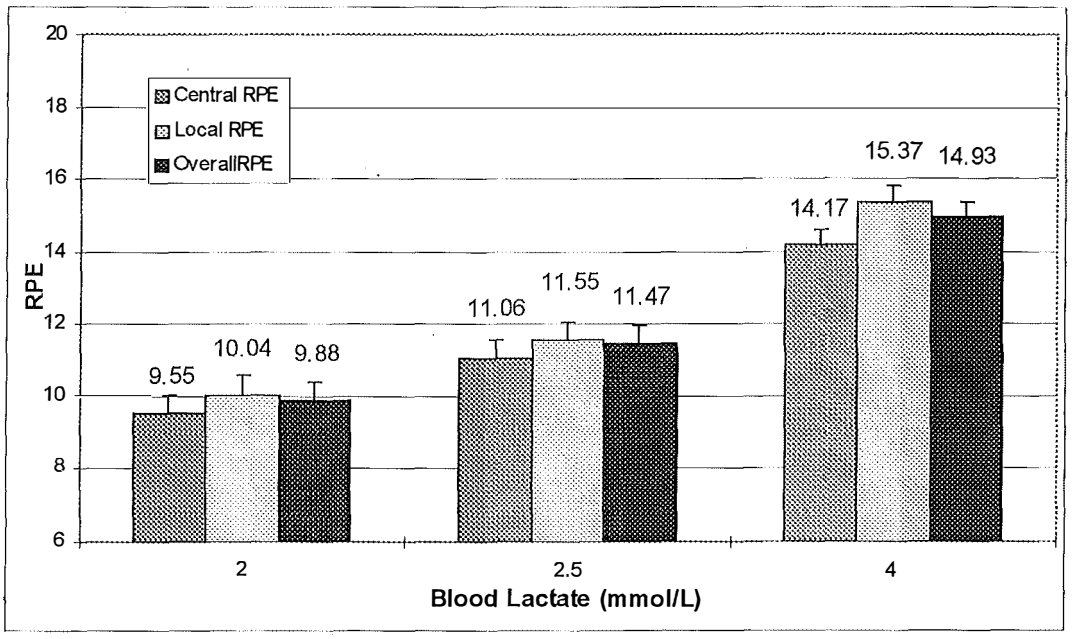

FIGURE 4.6 GROUP MEAN CENTRAL, LOCAL AND OVERALL RPE CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

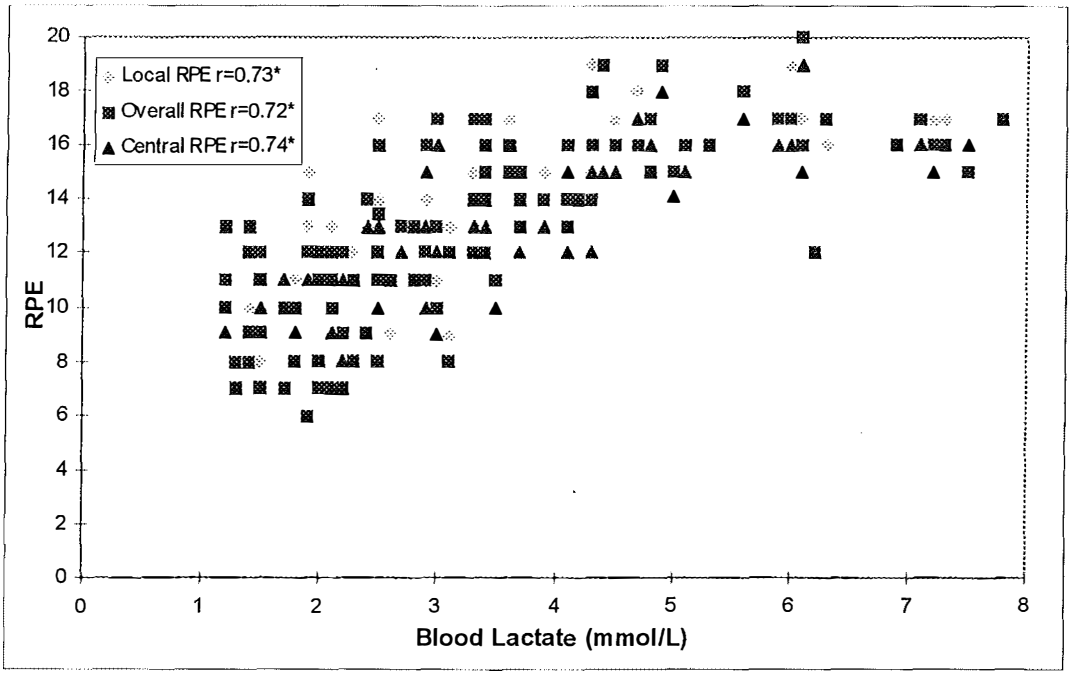

FIGURE 4.7 RELATIONSHIP BETWEEN CENTRAL, LOCAL AND OVERALL RPE CORRESPONDING TO INCREASES IN BLOOD LACTATE DURING EXERCISE (BOTH GROUPS COMBINED)

* Denotes highly significant positive correlation at the level of 0.001.

4.8 Central RPE

Mean central RPE values corresponding to 2.0, 2.5 and 4.0 mmol blood lactate are presented in figure 4.8. Mean central RPE corresponding with 2.0 mmol blood lactate was 10.4 ± 0.6 for HA and 8.6 ± 0.6 for LA. Central RPE corresponding to 2.5 mmol blood lactate was 12.0 ± 0.6 for HA and 10.1 ± 0.6 for LA. Central RPE corresponding to 4.0 mmol blood lactate was 15.1 ± 0.4 for HA and 13.2 ± 0.4 for LA. ANOVA analysis revealed the consistently lower central RPE values for LA to be statistically significant (p=.03). Independent t-tests were then performed in order to identify where significant differences occurred. The difference between HA and LA for central RPE corresponding to 2.5 mmol blood lactate was significantly different (p=0.04). The difference between HA and LA for central RPE corresponding to 4.0 mmol blood lactate was highly significant (p=0.01) indicating systematic differences in central RPE between the groups at higher exercise intensities.

4.9 Local RPE

Mean local RPE values corresponding to 2.0, 2.5 and 4.0 mmol blood lactate are presented in figure 4.9. ANOVA revealed no significant differences between HA and LA (p=0.06) however there was a consistent trend toward lower local RPE values at each of the blood lactate conditions for LA than for HA. Differences between the groups for local RPE corresponding to 4.0 mmol blood lactate were of the same relative magnitude (approximately 15%) as for central RPE.

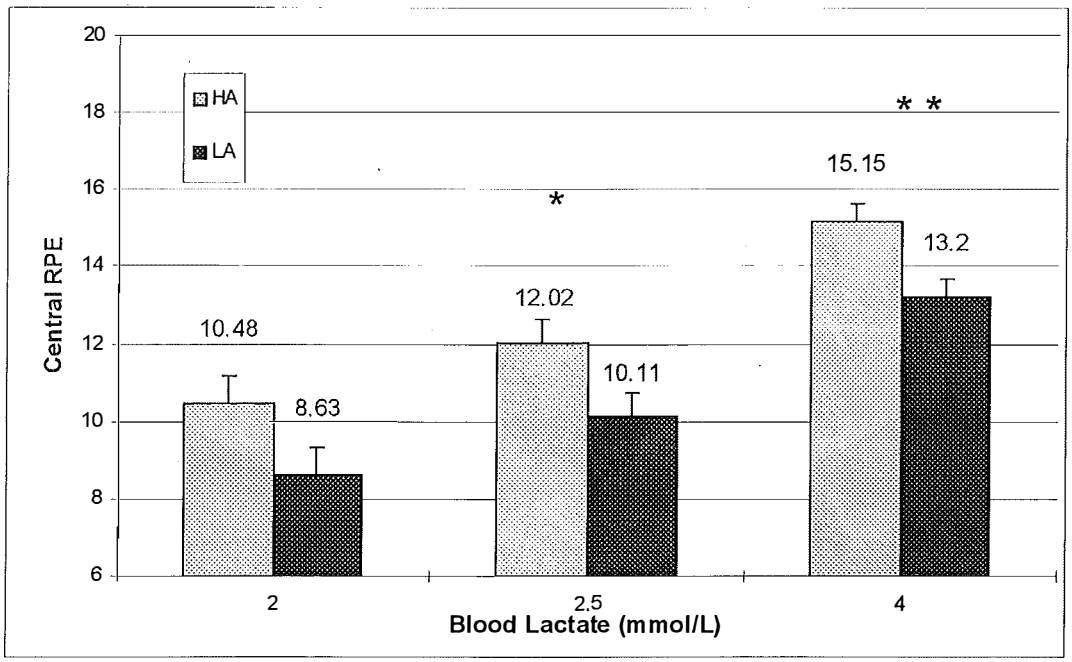

FIGURE 4.8 CENTRAL RPE CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

* Denotes significant difference at the level of 0.05 between groups.
** Denotes significant differences at the level of 0.01 between groups.

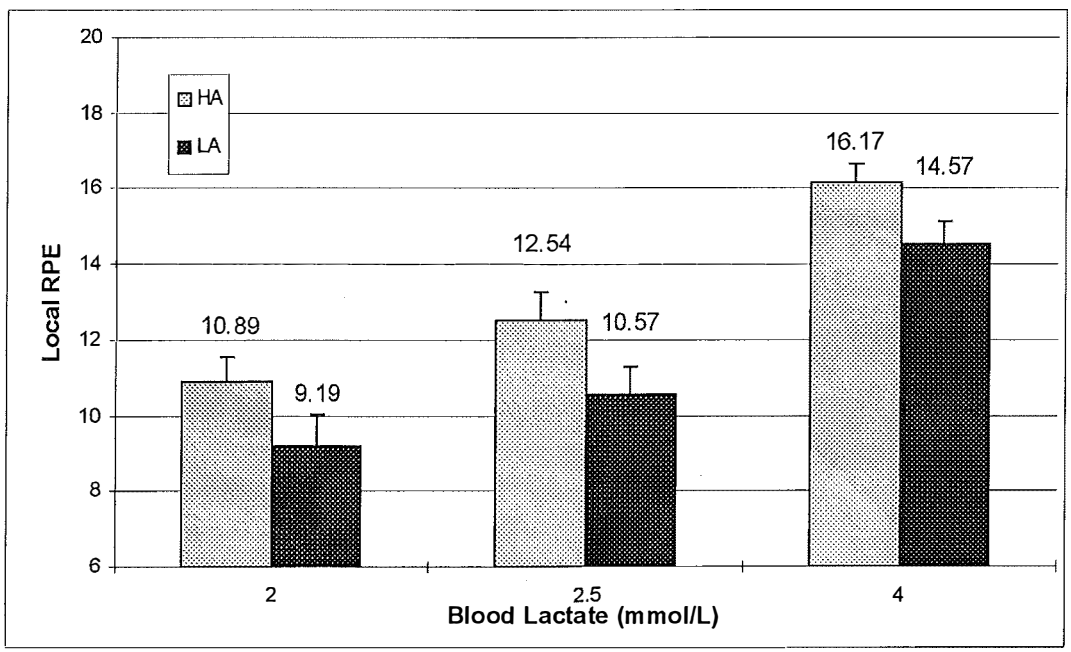

FIGURE 4.9 LOCAL RPE CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

4.10 Overall RPE

There was a trend at each of the measured blood lactate concentrations for overall RPE to be lower for LA than HA (Figure 4.10). This difference amounted to greater than 10% at each blood lactate condition. Mean overall RPE corresponding to 2.0 mmol blood lactate was 10.7 ± 0.4 for HA and 9.0 ± 0.8 for LA. Overall RPE values corresponding with 2.5 mmol blood lactate were 12.2 ± 0.6 for HA and 10.7 ± 0.7 for LA. Overall RPE values corresponding to 4.0 mmol blood lactate were 15.7 ± 0.4 for HA and 14.0 ± 0.5 for LA. ANOVA found differences between groups not to be statistically significant (p=0.08).

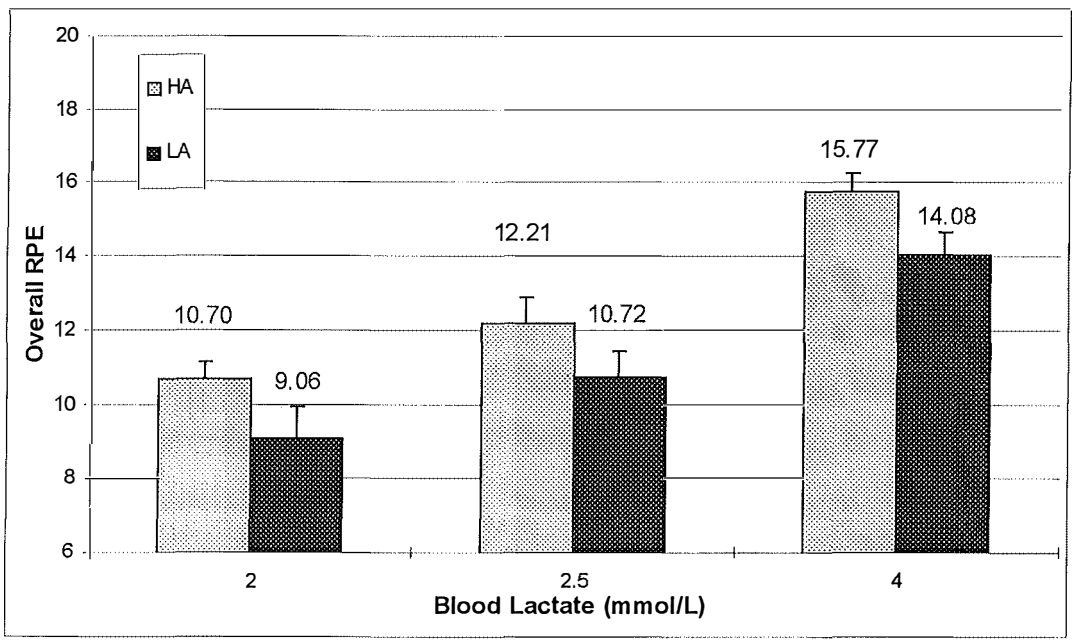

FIGURE 4.10 OVERALL RPE CORRESPONDING TO 2.0, 2.5 AND 4.0 mmol BLOOD LACTATE. (MEANS ± SEM)

CHAPTER 6

DISCUSSION

The purpose of this study was to compare the ability of subjects accustomed to regular vigorous physical activity (HA) with those accustomed to a more sedentary lifestyle (LA) in their ability to utilise subjective effort sense (RPE) to accurately estimate exercise intensities corresponding to 2.0, 2.5 and 4.0 mmol blood lactate, intensities prescribed by exercise specialists to improve endurance fitness and functional cardiovascular capacity. Data relating to regular physical activity levels, estimated VO_2 max and blood lactate response to exercise clearly suggest a large difference in the functional aerobic capacity between the two groups. Pencil and paper inventories such as the activity index questionnaire chosen for this study have been shown to provide a valid assessment of health related activity (Sharkey, 1991, p.63) and are capable of providing an estimate of endurance fitness. Mean estimated VO_2 max was 20% higher for HA than for LA. Although this was not significant it did indicate a large difference between the groups when compared to percentiles for the Australian population (Gore & Edwards, 1992, p.34). Perhaps most importantly, the fact that workload corresponding to 4.0 mmol blood lactate was 25% higher in HA than in LA indicated that exercise evoked a substantially different response from the groups for the key physiological variable measured during the study.

The results of the study confirm *hypothesis 1* that a strong positive correlational relationship exists between overall RPE and increases in blood lactate concentrations experienced during exercise despite differences between groups for workload, and heart rate.

Workload (Watts) as well as heart rate (BPM) corresponding to 2.0, 2.5 and 4.0 mmol blood lactate were significantly lower in LA than in HA. This reflects the higher degree of aerobic development in HA predicted by the activity questionnaire and estimated VO_2 max. Differences between high and low active individuals for workload and heart rate have been widely reported (Demello et al, 1987; Seip et al, 1991) and reflect hypoxic conditions which occur in the working muscles at a lower relative exercise intensity in untrained individuals, leading to increased reliance on anaerobic metabolism and, in turn, an earlier increase in the appearance of blood lactate during exercise.

Mean RPE values for both groups combined were 10-20% lower at each blood lactate concentration than previously reported (Seip et al, 1991; Demello et al, 1987; Pierce et al, 1990) possibly due to the fact that previous studies have used the venipuncture method to extract blood samples whereas the present study used the finger prick method. Sayed et al (1993) state that finger prick sampling will produce consistently higher blood lactate values when compared with venipuncture. This would explain the lower RPE values at a given blood lactate concentration. In addition, it has been shown that caffeine ingestion

(Weltman, 1995, p.41) and substrate availability (Ivy et al, 1981) can effect measurement of blood lactate. These factors were not controlled for during the study and so, despite instructions to participants to maintain normal eating habits and exercise routine prior to testing, it must be acknowledged that diet and prior exercise are factors which may have had an impact on results obtained in the study.

All subjects showed a marked dissociation of central and local RPE values as workload increased, local RPE rating as high or higher than overall RPE and consistently higher than central RPE at a workload eliciting 4.0 mmol blood lactate. Again this phenomenon has been previously reported (Pandolph, 1982) and is thought to be due to the influence of local factors on RPE during cycle ergometry. Previous research (Robertson et al, 1979) suggests that overall RPE approximates the average of local and central components. This was found to be the case in this study, the mean of central and local RPE generally falling within 0.25 of 1 overall RPE value at all blood lactate conditions whether results for both groups were combined or taken separately. These findings reinforce the theory (Robertson et al, 1979) that overall RPE is not directly related to discrete physiological events but is an integration of a number differentiated sensations.

Hypothesis 2-4 respectively, stated that there would be no significant differences in central, local and overall RPE values corresponding to 2.0, 2.5 and 4.0 mmol blood lactate in highly active compared to low active individuals. Despite strong evidence in previous literature, supported by the results of this study that a strong

relationship between RPE and the blood lactate response to exercise did exist when the mean scores of the two groups were combined, this study produced statistically significant differences between the two experimental groups for central RPE and consistent (but not statistically significant) differences in reported local and overall RPE values between the two experimental groups. The LA group reported central, local and overall RPE values which were consistently 15-20% lower than the HA group at each of the blood lactate conditions.

The greater central RPE values reported by HA is probably due to differences in the relative exercise intensity at which each of the three blood lactate conditions occurred. Although it was not practical during this study to directly measure VO_2, studies by Macrae et al (1991) and Weltman (1995, p.43) support the conclusion that a larger functional aerobic capacity as displayed by HA would result in a given quantity of blood lactate occurring at a higher relative exercise intensity in HA than in LA. It follows then, that the greater relative V_E and $\%VO_2$ corresponding to 2.0, 2.5 and 4.0 mmol blood lactate in HA would result in a greater central contribution to effort sense for that group. This phenomenon has been previously reported. Seip et al (1991) found that central RPE was higher in trained runners than in novice runners during treadmill exercise at workloads corresponding to 2.5 and 4.0 mmol blood lactate. During the present study, exercise intensity corresponding to 4.0 mmol blood lactate occurred at 80% and 73% age predicted maximum heart rate for HA and LA respectively, reinforcing the possibility of a greater central stimulus for HA than for LA.

The trend toward higher local RPE values for HA compared to LA suggests that blood lactate, rather than being the catalyst, is only one of a number of contributors to local effort sense. If it was the case that blood lactate was the primary contributor then it appears reasonable to assume that at the fixed blood lactate concentrations measured in this study local RPE values would not have differed between groups. The differences between the groups although not statistically significant were remarkably consistent across the three blood lactate conditions.

In addition it is perhaps surprising that LA reported lower RPE values than HA. Common experience would suggest that at a given relative workload individuals less experienced at that workload might be expected to perceive more effort than those with greater experience. The answer to this puzzle may lie in the kinetics of lactate metabolism. As previously discussed, individuals who display an "endurance" type lactate profile can maintain low levels of blood lactate at high relative workloads. This is often followed however by a very sharp rate of increase in the appearance of blood lactate not seen to the same extent in lesser adapted individuals. HA displayed a higher (12%) rate of increase in the appearance of blood lactate than LA during the workload at which 4.0 mmol blood lactate was recorded. It may be the case that blood lactate efflux from muscle to blood is rate limited during this sharp rate of increase in blood lactate production seen in more highly adapted individuals, leading to increases in muscle lactate and a heightened sense of effort. This indicates that muscle lactate may have a substantial influence

on local RPE at relatively high exercise intensities. Further evidence for this argument can be found in investigations conducted at altitude which have found that following acclimatisation large increases in muscle lactate efflux from the legs is accompanied by decreases in reported overall RPE values (Young, 1990; Green et al, 1989).

Differences between HA and LA for overall RPE again, though not statistically significant were highly consistent across each of the three blood lactate conditions. It appears likely that this was due to differences in the mode of integration of the differentiated sense of effort. Robertson et al (1979) found that overall RPE values approximated the mean of the central and local signals at all workloads. It is also well documented (Robertson, 1979; Pandolph, 1982; Carton & Rhodes, 1985) that in activities such as cycling local RPE dominates the overall perception of effort due to the fact that local signals of perception originate from one major source. The latter argument was supported by the results of this study. Pandolph (1982) however, suggests that when pronounced regional feedback stems from two sources as is the case when running, the undifferentiated perception forms a gestalt which is set higher than either differentiated signal. Carton and Rhodes (1985) state that this effect can only be achieved above a critical work threshold and is a result of increased input from central signals of effort sense. If this chain of events does occur then it may well be responsible for the higher overall RPE values reported by HA than for LA. Robertson (1982) postulates that the ability to raise the awareness of effort may act as a warning that a critical point is approaching

both for the musculoskeletal (local) and cardiorespiratory (central) contributors to effort. This finding agrees with those of Carton and Rhodes (1985) who found that there may well be differences in the differentiated perception of effort that may only be detectable at extremes of exercise. The sharp exponential rise in blood lactate experienced by adapted individuals at high workloads as well as the high $\%VO_2$ at which these events begin to take place may produce such conditions. Untrained individuals would display a rise in blood lactate at a much lower relative exercise intensity and so would not have to contend with near maximal signals of effort produced by central as well as local factors. This may account for the relatively high overall RPE values reported by HA during the study. Further evidence for this argument is supplied by Allen and Pandolph (1977) who manipulated lactate production by asking subjects to breathe hyperoxic gas mixtures during exercise. The result was that work capacity increased while blood lactate decreased. RPE values remained constant. The authors concluded that the resulting sense of effort was a mixture of relative workload and blood lactate levels.

The concept that overall RPE is mediated by the relative input of differentiated effort sense has important implications for exercise prescription utilising RPE. The results of this study in no way detract from the value of RPE as a simple, reliable tool for use in exercise prescription in a variety of settings. The results do however, point to the need for further study into the complex relationships involved in undifferentiated effort sense and to recognise that certain groups who

experience extreme regional physiological responses at relatively low exercise intensities as is often seen in diseased populations may need to adapt guidelines for exercise incorporating RPE in order to account for a potential modification of the signal of effort sense which may only be visible under extreme physiological conditions.

In terms of the general population the results of this study confirm that exercise intensity corresponding to RPE values of between 9 and 15 will result in a reliable estimation of a training intensity required for improvements in cardiorespiratory fitness and endurance performance based on the blood lactate response to exercise and that the testing protocol employed during this study has the potential to provide the basis of exercise prescription using RPE. The ability of subjects to produce workloads estimated during testing would have to be confirmed however, a task beyond the scope of this study.

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APPENDIX A

Health Risk Questionaire

Pre Test questionnaire

Personal details

Name

Age D of B Gender

Address

Contact phone numbers

Occupation Employer

Emergency contact number Regular physician

Medical

1. Has your doctor ever said that you have heart trouble ?
2. Do you frequently have pains in your heart or chest region?
3. Do you often feel faint or have severe dizzy spells?
4. Has your doctor ever told you that your blood pressure is too high and that you may have a problem with your blood pressure?
5. Do you have any bone or joint problems such as arthritis or an old sporting injury which you or your doctor think may be made worse if you exercise? Please list
6. Have you ever suffered from a stroke?
7. Are you male and over 35 years or female and over 45 years?
8. Is there any other medical or health reason that you can think of which would prevent you from undertaking a fitness evaluation and increasing your physical activity? Please list
9. Do you take any medication which you or your doctor think may affect our fitness measurements or affect you during or after a fitness evaluation or during an exercise programme?
10. Are you on any medication at all at the moment?

APPENDIX B

Informed Consent / Information Sheet

INFORMED CONSENT FOR VOLUNTARY PARTICIPATION IN:

A RESEARCH STUDY EXAMINING THE RELATIONSHIP BETWEEN THE BLOOD LACTATE RESPONSE TO EXERCISE AND SUBJECTIVE RATINGS OF PERCIEVED EXERTION AT VARIOUS EXERCISE INTENSITIES.

Introduction

The prescription of exercise intensity in endurance exercise can be guided by a variety of physiological/psychophysical markers.

Traditionally the most common methods for predicting exercise intensity are based on a fixed percentage of maximal oxygen consumption (VO_2 MAX), or a fixed percentage of maximal heart rate. (Steed, Gaesser & Weltman, 1994).

Subjective ratings of perceived exertion is a subjective measure of exercise intensity based on a combination of central and peripheral feelings of strain on the part of the subject. The concept of measuring feelings of exertion first appeared in the literature in 1961 (Dunbar, Robertson, Baun, Metz, Burdett & Goss, 1991), and has recently been applied to exercise prescription in the general fitness, clinical and athletic settings (Demello, Cureton, Boineau & Singh, 1987).

The lactate threshold is the highest intensity of exercise that can be attained before a continual increase in blood lactate accumulation is observed. The build up of lactate in the muscles and blood is a limiting factor in endurance exercise (Powers & Howley, 1994). For this reason there is evidence to suggest that exercise prescription based on the measurement of blood lactate concentrations at or near the lactate threshold are a more appropriate predictor of exercise intensity than either a fixed percentage of VO_2 max or maximal heart rate (Weltman, 1995, pV).

Disadvantages with the prescription of exercise based on lactate threshold include the invasive nature of the procedure (blood samples need to be taken from the subject) and the expense of the laboratory equipment required. Recent studies suggest that the use of rate of perceived exertion as the tool for designing exercise prescription based on blood lactate concentration's coinciding with the lactate threshold will provide a safe, effective and convenient method for designing and monitoring exercise programs (Weltman, 1995, p 156).

Purposes of the study

To investigate the relationship between the blood lactate response to exercise and RPE in highly active and low active individuals.

To investigate the relationship between central and peripheral signals of effort sense in highly active and low active individuals.

Procedures

The study requires the subjects to perform an incremental cycle ergometer test. Exercise intensity will be increased every four minutes throughout the test, which will be concluded when the workload elicits a moderately high exercise response. (Take note that the test is not maximal.).

Every four minutes throughout the course of the test a finger tip blood sample will be taken. In addition, blood samples will be taken pre and post exercise. A total of approximately ten blood samples may be required throughout the course of a testing session.

The subject will be rquired to wear a Polar PE 4000 heart rate monitor throughout the course of the test. This consists of a wrist watch reciever and a chest strap worn by the subject. In addition, basic physiological data e.g. age, height, weight, mass, will be measured.

Time requirements

Participation in the study will require approximately one hour to complete. Times will be arranged to suit the subject.

Possible benefits of participation in the study

Subjects will obtain an assessment of their lactate profile. This is difficult and expensive data to obtain outside the laboratory setting and can be used to identify optimal intensity of exercise for improvements in functional aerobic capacity. This information is useful to both athletes and non athletes.

The development of safe, simple and appropriate methods of prescribing and monitoring cardiovascular training intensity is important in both the athletic and clinical settings.

Ethics

The highest ethical standards will be maintained throughout the course of the study.

In order to maintain the confidentiality each participant will be assigned a number which will be used in place of their name throughout the course of the study. In addition the study has the approval of the Edith Cowan ethics committee.

Withdrawal from the study

Any person who chooses to participate in the study is free to withdraw from the study at any time and for any reason. There is no obligation to continue and no penalty whatsoever for withdrawal.

Questions

Any questions regarding any of the issues or procedures discussed in this handout can be directed in the first instance to:

Keith Scotson	Student Researcher	Tel: 367 4745
Dr. Paul Sacco	Principal Researcher	Tel: 400 5642

I..... Have read the information supplied in this handout and have had any questions regarding my involvement in the study answered to my satisfaction. I agree to participate in the study on the understanding that I may withdraw at any time without penalty of any kind.

In addition I agree that any research data gathered throughout the course of the study may be published provided my anonymity is assured.

..... Date

Participant

..... Date

Researcher

REFERENCES

Demello, J., Cureton, K., Boineau, R. & Singh M. (1987). Ratings of perceived exertion at the lactate threshold in trained and untrained men and women. Medicine and Science in Sports and Exercise. 19: 354-362.

Powers, S. and Howley, E. (1994). Exercise physiology (2nd ed). Dubuque. Wm C Brown.

Steed, J., Gaesser, G. & Weltman, A. (1994). Ratings of perceived exertion (R.P.E.) as markers of blood lactate concentration during rowing. Medicine and Science in Sport and Exercise 26, 797-803.

Weltman, A. (1995). The Blood Lactate Response To Exercise. Champaign. Human Kinetics.

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Possible benefits of participation in the study

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In addition I agree that any research data gathered throughout the course of the study may be published provided my anonymity is assured.

..... Date

Participant

..... Date

Researcher

REFERENCES

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Weltman, A. (1995). The Blood Lactate Response To Exercise. Champaign. Human Kinetics.

INSTRUCTIONS FOR PARTICIPANTS

Your participation in this study is greatly appreciated. The results obtained during the study can be affected by certain factors and so it would be greatly appreciated if you would follow some simple guidelines in the days leading up to the testing sessions.

1/. Try to consume as close to your "normal" diet in the two days prior to a testing day as possible.

2/. Try to avoid moderate to heavy exercise in the two days prior to a testing day.

3/. Try to avoid excessive alcohol intake the day prior to a testing day.

4/. Please inform the researcher prior to testing if any of the above criteria were not met.

Again, thankyou for your participation in this study. By following the guidelines explained on this page results obtained during the study will have greater validity and will ensure that your time contribution provides valuable data.

APPENDIX C

Activity Index Questionaire

Activity Index: Based on your regular daily activity, calculate your activity index by multiplying your score for each category (score = frequency x intensity x time).

	Score	Daily Activity
Frequency	5	Daily or almost daily
	4	3 to 5 times per week
	3	1 to 2 times per week
	2	A few times per month
	1	Less than once per month
Intensity	5	Sustained heavy breathing and perspiration(Running etc)
	4	Intermittent heavy breathing and perspiration- as in tennis racquet ball or light jogging).
	3	Moderately heavy-as in recreational sports orcycling
	2	Moderate- as in volleyball and softball
	1	Light-as in fishing and walking
Time	4	Over 30 min
	3	20 to 30 min
	2	10 to 20 min
	1	Under.10.min

Name: **ContactTelephone**

Evaluation And Fitness Category

Score	Evaluation	Fitness Category
100	Very active	High
80-100	Active and healthy	Very good
40-60	Acceptable	Fair
20-40	Not good enough	Poor
Under 20	Sedentary	Very poor

Source: Sharkey (1991) In New Dimensions In Aerobic Fitness. Champaign. Human Kinetics

N.B: For the purposes of the study subjects who score 80 or above will be placed in the high active category. Subjects who score 40 or below will be placed in the low active category.

APPENDIX D

Physical Characteristics of The Experimental Groups

Physical characteristics of HA and LA groups. Data are presented as means and ±standard error of the mean (SEM).

Variable	High Active (n=10)	Low Active (n=10)
Age (Years)	25.3 ± 2.6	25.5 ± 2.6
Mass (Kg)	67.45 ± 3.8	68.5 ± 3.1
Body Mass Index	23.1 ± 0.7	23.2 ± 0.6
Estimated VO_2 max(ml/kg/min)	52.91 ± 3.81	42.97 ± 3.41
W/load at 4.0mM Hla(Watts)*	178.5 ± 21.2	113.7 ± 11.7
Activity Score**	88.0 ± 3.3	29.6 ± 2.8

* Denotes significant differences at the 0.05 level.

** Denotessignificant differences at the 0.01 level.

APPENDIX E

Adjusted Nomogram For Calculation of VO_2 max

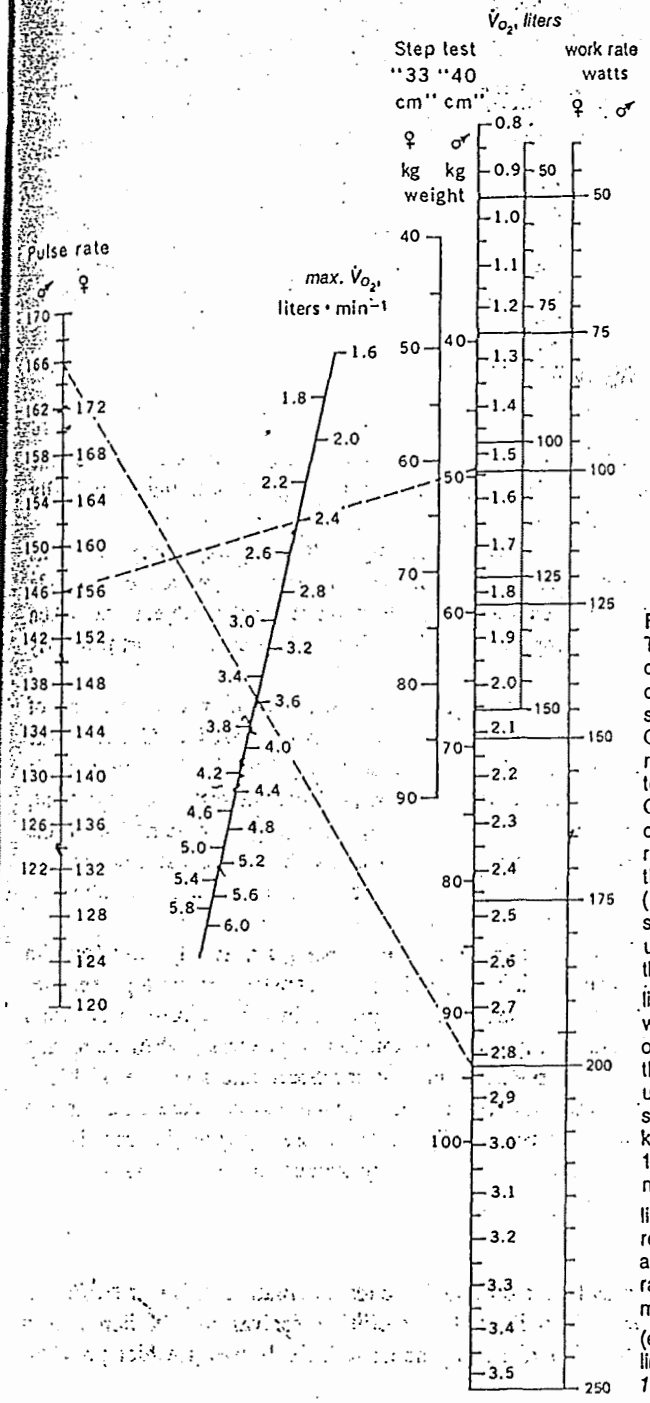

Figure 8-4
The adjusted nomogram for calculation of maximal oxygen uptake from submaximal pulse rate and O_2-uptake values (cycling, running or walking, and step test). In tests without direct O_2-uptake measurement, it can be estimated by reading horizontally from the "body weight" scale (step test) or "work rate" scale (cycle test) to the "O_2 uptake" scale. The point on the O_2-uptake scale ($\dot{V}_{O_2}$, liters) shall be connected with the corresponding point on the pulse rate scale, and the predicted maximal O_2 uptake read on the middle scale. A female subject (61 kg) reaches a heart rate of 156 at step test; predicted max. $\dot{V}_{O_2}$ = 2.4 liters · min^{-1}. A male subject reaches a heart rate of 166 at cycling test on a work rate of 200 watts; predicted max. $\dot{V}_{O_2}$ = 3.6 liters · min^{-1} (exemplified by dotted lines). *(From I. Åstrand, 1960.)*

Astrand, P. & Rodahl, K. (1986). Textbook of Work Physiology (3rd ed). Singapore: Mcgraw-Hill

APPENDIX F

Description of Acusport Portable Lactate Analyser

The Boehringer Manheim portable lactate analyser is a portable lactate analysis machine often used in the field as well in the laboratory setting by exercise scientists and coaches to obtain measurement of blood lactate concentration. Advantages of the Accusport are considered to be:

- The unit is portable (Similar size to a pocket calculator)
- Simple to use (Utilizes test strip technology to analyze blood samples
- Displays results within 60 seconds.

Test Principle

Blood seeps through the yellow protective mesh into a glass fibre fleece where erythrocytes are retained. Plasma continues on to a detection film. Lactate concentration is determined by reflectance photometry via a colorimetric lactate oxidase mediator reaction. **Only capillary blood may be used.**

Calibration

Each pack of test strips contains it"s own calibration test strip. The meter will not accept a lactate test strip for which it has not been calibrated.

Technical Data

Parameter	Lactate
Measuring system	Accusport meter and BM Lactate test strips
Sample material	Capillary blood drawn fom finger tip.
Display	Display of either blood or plasma readings.
Measuring range	0.8-22mM/L.
Measuring time	60 seconds.
Storage capacity	100 values with date and time.
Technology	Reflectance photometry.
Dimensions	11/5 x 6/2 x 1/85 cm.
Weight	120g (including batteries)
Power source	3 x 1.5 volt batteries
Accuracy	Batch specific coding.
	Code checked for each test strip.

APPENDIX G

A.C.S.M. Safety Guidelines

Code of Practice for Blood Sampling

Many test protocols used for physiological assessment of athletes require taking small samples blood. The following practices are recommended for working with blood samples:

- Ask in private and confidentially if the subject is known to have carried or to be suffering fro AIDS or Hepatitis B. Subjects in this category need specialised sampling techniques involvi additional protection and medical supervision. Blood samples from ALL individuals shou be treated as if contaminated, i.e. precautions taken to prevent virus transmission.
- Exclude subjects who have any obvious wounds on the hands.
- Any cuts on the tester's hands or wrists should be covered with waterproof adhesive dressir before taking samples.
- Regularly laundered laboratory coats should be worn.
- Wash hands thoroughly with soaps and water, using nail brush if necessary.
- Disposable gloves should be worn when taking and handling samples. Change gloves betwee subjects if blood is on the glove. The U.S. Centre for Disease Control (CDC) recommenc changing gloves between each subject when blood is withdrawn. Gloves should also be wor whenever blood samples or parts (e.g. supernatants, cells) of blood samples are handle including transport of samples and performing assays.
- A no-touch technique is employed.
- Swab the site of the puncture: dispose of swab in the hazard bag. Standardise the site puncture and the posture of the subject (generally supine) to ensure validity and consisten of results.
- For small samples, stab the cleaned area with a lancet or autolet and take 50 microliti sample into the capillary tube. "Milk", but do not squeeze the area of the puncture as th causes interstitial fluid to leak into the blood, thereby artificially altering the concentratior of substances being measured.
- Transfer of lancets and needles immediately after blood sampling. Do not recap needl unless a specific device is used to prevent percutaneous injury. Used lancets should be place in a sharpkeeper container marked with the OSHA Biohazard symbol. The sharpkeep should be sealed when the experiment is finished and placed in a yellow clinical waste ba marked 'Clinical Waster' for incineration. Discarded capillary tubes should be treated in th same manner. Used swabs and all non-sharp material should be placed in a clinical was disposal bag.
- Cover the puncture site with waterproof adhesive dressing.
- Any blood contaminating the experimenter should be washed off with soap and water.
- Any spillage of blood should be cleaned with a swab containing bacteriocide or 2% sodiu hypochlorite solution.

1.2 Finger Tip samples

i. Swab the fingertip firmly to get rid of sweat, dirt and water and dry with a tissue.

ii. Press the lancet onto the fingertip supporting the finger with the other hand.

iii. Firmly prick the fingertip on the rim avoiding the freshy centre.

iv. Wipe away the first blood droplet.

v. Continue as with earlobe sampling.

Hints for fingertip sampling:

- Care should be taken with the use of Finalgon (vasodilator which enhances the blood flow to the region) as some individuals have strong skin reaction to the cream.
- Firm prick to the site.
- Subject should be encouraged to shake hands in air before sample is taken (for fingertip samples).
- Subject tested outdoors should wear gloves/hats to keep lactate sample site warm.

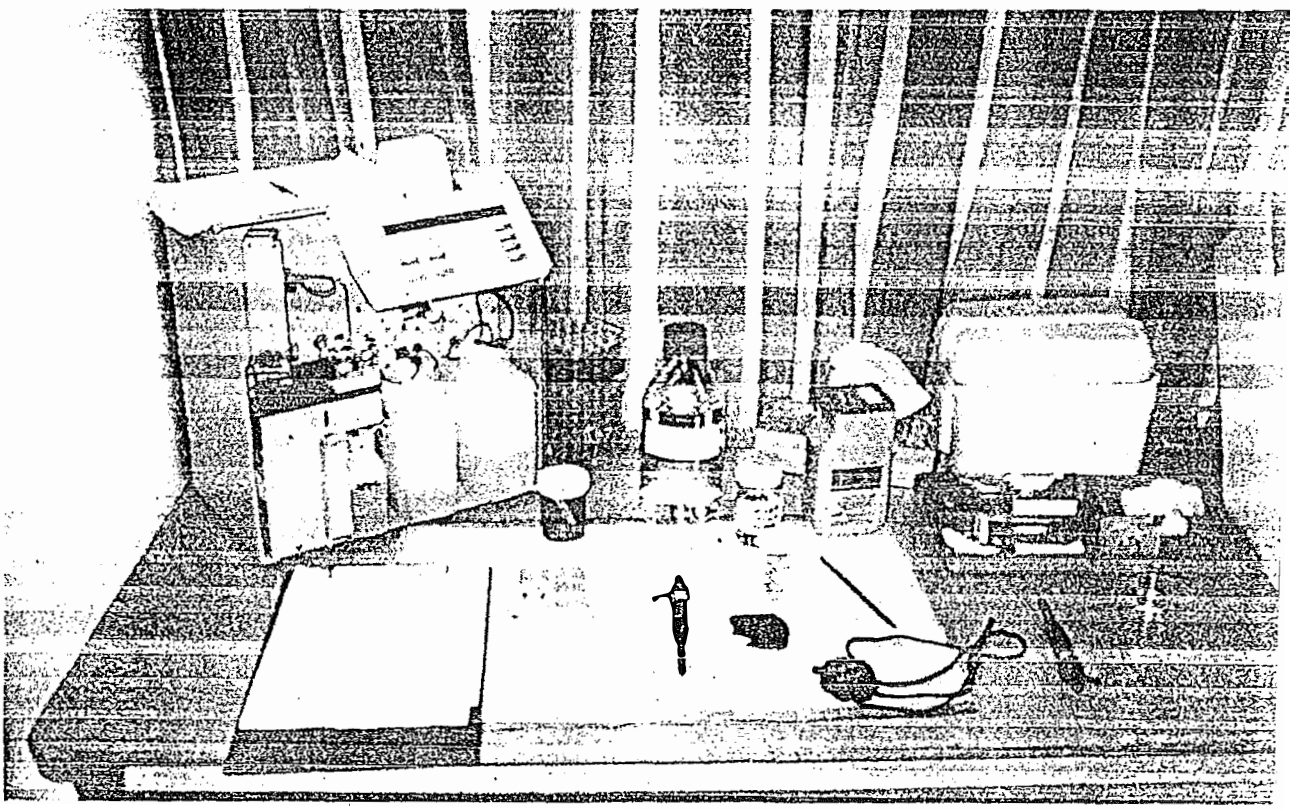

FIGURE 5.2 - Equipment for Blood Lactate Analysis.

- Scrub down thoroughly any parts of equipment contaminated by blood.
- Wash hands before leaving laboratory.
- Report all needlesticks immediately to a supervisor and to a physician to determine if fo up care is required.
- Hepatitis B vaccines are now freely available at minimal charge and are recommended fo personnel routinely involved in sampling human fluids.
- Specimens containing blood or parts of blood should be transported in sealed leak-p containers, preferably double sealed to prevent contamination in the event of tube break leakage or opening.
- No food or drink should be stored or consumed in a laboratory where blood, saliva or o body fluids are sampled. Drinks used by subjects during prolonged tests for maintai hydration must be prepared and stored away from the laboratory.

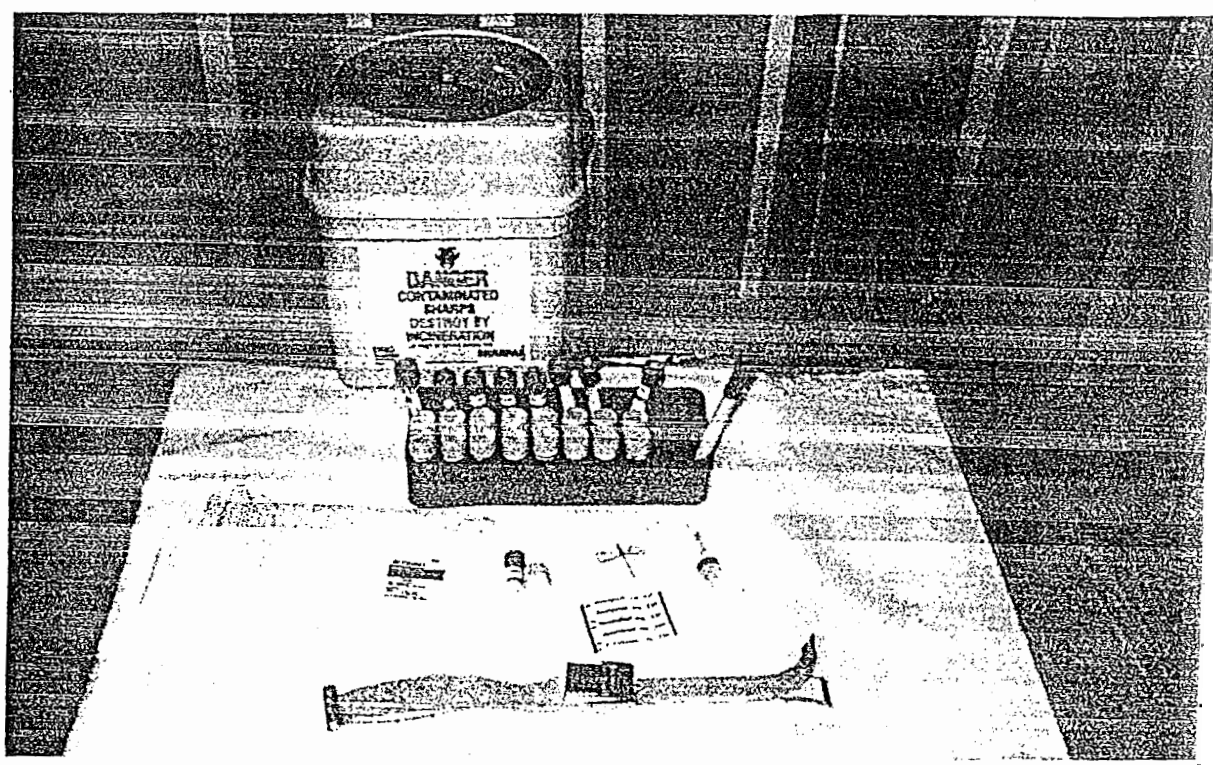

FIGURE 5.1 - Equipment for Blood Sampling.

URCE

erican College of Sports Medicine (1986). Guidelines for graded Exercise Testing
Exercise Prescription (3rd ed). Philadelphia. Lea and Febiger.

APPENDIX H

Data Collection Sheet

DATA COLLECTION SHEET

Date..... Time.....

Subject Number..... Age.....

Height.....

Body mass..... Sex.....

Body mass index..... Activity Index Score.....

Workload (Watts)	Heart rate	HLa	RPE CENTRAL	R.P.E. LOCAL	RPE OVERALL
REST					
40					
65					
90					
115					
140					
165					
190					
215					
40					
40					

Comments:

APPENDIX I

Standard RPE Instructions

APPENDIX 1.

Instructions to the Subject

(These instructions - or the main content of them - may be read to the subject or he/she can be given them to read.)

During the exercise we want you to rate your perception of exertion, e.g. how hard and strenuous you feel the exercise to be. By perceived exertion we mean all your sensations and feelings of physical stress, effort and fatigue in your whole body, coming from your legs, your chest and your breathing etc.

We want you to use this rating scale from 6 to 20, where 6 means no exertion at all, that is your condition when you are thoroughly rested, and 20 means the maximal exertion, that is the utmost strenuous effort and exertion highest possible.

Between 7 and 8 you have an extremely light effort and exertion, like walking very slowly. 9 is a very light exercise, like walking slowly for some minutes for healthy people.

As the exercise intensity increases you will perceive it to be more and more strenuous and you should use a higher and higher rating figure. 13 on the scale is a somewhat heavy exercise but it still feels fine and you should not have any problems to continue exercising.

When you come to 17, "very hard", it is really very strenuous, you can still go on but you have to push yourself very much. 19 on the scale is an extremely strenuous as they have ever experienced before, in e.g. running extremely hard or lifting or carrying something ex-running extremely hard or lifting or carrying something extremely heavy, so heavy that they can barely manage it. For most people that will be equal to the heaviest or hardest physical exercise they have ever done.

You may, however, imagine physical effort that is even more stressful than 19. So a more true or "absolute" maximum is slightly more than 19, that is 20.

SOURCE:
BORG, G. (1986) AN INTRODUCTION TO BORG'S RPE SCALE. MICHEGAN. MOUVEMEND PUBLICATIONS.

It is very important that you try to appraise - estimate - your feeling of exertion as honestly and accurately as possible. Don't underestimate it, but don't overestimate it either. Don't bother about what the exercise or the physical work load objectively might be. We are not interested in that but only in your own feeling of effort and exertion. Some people are a bit insensitive or want to be "brave" and rate too low. Don't do that but try to feel your exertion and appraise it as correctly as possible.

When we ask you "How strenuous is the exercise?", "How hard do you feel it to be?", you should answer with a figure. Look first at the verbal expressions on the scale and then select a number. You can equally well use an even as an odd number.

During the exercise the heart rate increases more and more so we can use it to predict your performance capacity. The ratings should increase steadily in a similar way so we can also use them to predict your working capacity. Most people are very sensitive to feelings of effort and exertion and have no problem in giving a good estimate of the physical strain. It is very important that you seriously try to be as honest as possible so that we can use your ratings and their steady increase with the exercise intensity to predict your working capacity.

APPENDIX J

Tabulated Data

		Workload At 2.0, 2.5 and 4.0mM HLa						
HA GROUP								
subject	2.0mM	2.5mM	4.0mM	gender	age	bmi	q score	mass
13	147	220	269	m	23	22.84	80	82
17	100	194	249	m	17	23.12	100	70.3
5	160	190	234	m	33	22.04	100	69
4	155	190	244	m	20	24.34	100	73.7
2	135	145	163	m	21	27.75	80	85
11	115	129	171	f	37	22.64	100	53
15	77	90	125	f	19	24.49	80	75.7
20	43	49	68	f	19	19.72	80	55
3	60	65	130	f	24	21.52	80	58.6
14	70	90	132	f	40	22.57	80	52.25
mean	106.2	136.2	178.5		25.3	23.103	88	67.455
sd	42.39706	60.75781	67.01119		8.260347	2.126474	10.32796	12.06705
se	13.4	19.22	21.2		2.61	0.67	3.26	3.81
LA GROUP								
10	82	124	155	m	24	24.62	36	78.2
12	50	66	120	m	17	23	24	70.4
19	119	134	166	m	32	23.37	24	72.4
9	35	75	101	m	31	24.48	36	75.4
6	30	70	154	m	27	23.85	40	79.9
1	92	101	132	f	30	23.14	32	63.8
7	65	73	90	f	18	23.32	16	69
16	40	55	84	f	18	18.9	36	54
8	25	43	65	f	23	21.85	36	50.5
18	20	47	70	f	35	25.03	16	71.1
mean	55.8	78.8	113.7		25.5	23.156	29.6	68.47
sd	32.80854	31.14768	37.00766		6.485025	1.757721	8.884443	9.740072
se	10.37	9.85	11.7		2.04	0.55	2.81	3.08

		Heart Rate At 2.0, 2.5 and 4.0mM HLa						
HA GROUP								
subject	2.0mM	2.5mM	4.0mM	gender	age	bmi	q score	mass
13	124	133	154	m	23	22.84	80	82
17	100	136	164	m	17	23.12	100	70.3
5	133	144	153	m	33	22.04	100	69
4	127	144	171	m	20	24.34	100	73.7
2	118	122	148	m	21	27.75	80	85
11	124	131	152	f	37	22.64	100	53
15	128	136	158	f	19	24.49	80	75.7
20	129	134	153	f	19	19.72	80	55
3	65	100	148	f	24	21.52	80	58.6
14	115	131	163	f	40	22.57	80	52.25
mean	116.3	131.1	156.4		25.3	23.103	88	67.455
sd	20.309	12.66184	7.501111		8.260347	2.126474	10.32796	12.06705
se	6.41	4	2.37		2.61	0.67	3.26	3.81
LA GROUP								
10	96	123	147	m	24	24.62	36	78.2
12	97	104	132	m	17	23	24	70.4
19	106	115	138	m	32	23.37	24	72.4
9	103	122	140	m	31	24.48	36	75.4
6	93	103	142	m	27	23.85	40	79.9
1	105	112	128	f	30	23.14	32	63.8
7	127	135	152	f	18	23.32	16	69
16	110	128	160	f	18	18.9	36	54
8	100	117	144	f	23	21.85	36	50.5
18	102	122	146	f	35	25.03	16	71.1
mean	103.9	118.1	142.9					
sd	9.573691	10.07141	9.290975		25.5	23.156	29.6	68.47
se	3.02	3.18	2.93		6.485025	1.757721	8.884443	9.740072
					2.04	0.55	2.81	3.08

		Central RPE At 2.0, 2.5 And 4.0mM						
HA GROUP								
subject	2.0mM	2.5mM	4.0mM	gender	age	bmi	q score	mass
13	11.5	12.55	15.15	m	23	22.84	80	82
17	8	13.45	16.45	m	17	23.12	100	70.3
5	14.45	16	17.6	m	33	22.04	100	69
4	10.5	12	14.45	m	20	24.34	100	73.7
2	10.55	11.4	14.9	m	21	27.75	80	85
11	12	12.6	15.9	f	37	22.64	100	53
15	12	13	16.8	f	19	24.49	80	75.7
20	9.3	10.1	12.4	f	19	19.72	80	55
3	7	9.1	13.5	f	24	21.52	80	58.6
14	9.5	10	14.4	f	40	22.57	80	52.25
mean	10.48	12.02	15.155		25.3	23.103	88	67.455
sd	2.161301	2.003913	1.57682		8.260347	2.126474	10.32796	12.06705
se	0.68	0.63	0.49		2.61	0.67	3.26	3.81
LA GROUP								
10	9.8	12.4	14.15	m	24	24.62	36	78.2
12	6.75	8	14.25	m	17	23	24	70.4
19	11.1	11.75	13.2	m	32	23.37	24	72.4
9	6.8	9.05	12.8	m	31	24.48	36	75.4
6	7.15	9.5	13.6	m	27	23.85	40	79.9
1	12.2	12.85	14.6	f	30	23.14	32	63.8
7	11	12.25	15.45	f	18	23.32	16	69
16	8	9	11.5	f	18	18.9	36	54
8	7	8.5	12	f	23	21.85	36	50.5
18	6.5	7.8	10.45	f	35	25.03	16	71.1
mean	8.63	10.11	13.2		25.5	23.156	29.6	68.47
sd	2.172965	1.975657	1.536229		6.485025	1.757721	8.884443	9.740072
se	0.68	0.62	0.48		2.04	0.55	2.81	3.08

		Local RPE At 2.0, 2.5 And 4.0mM						
HA GROUP								
subject	2.0mM	2.5mM	4.0mM	gender	age	bmi	q score	mass
13	10.75	12.15	15.25	m	23	22.84	80	82
17	8	13.25	17.45	m	17	23.12	100	70.3
5	15.4	17	18.55	m	33	22.04	100	69
4	10.8	13	15.15	m	20	24.34	100	73.7
2	11.55	12.4	15.9	m	21	27.75	80	85
11	11	12.1	17.45	f	37	22.64	100	53
15	12	14	17.8	f	19	24.49	80	75.7
20	11.4	12.5	15.3	f	19	19.72	80	55
3	8	8	13.5	f	24	21.52	80	58.6
14	10	11	15.35	f	40	22.57	80	52.25
mean	10.89	12.54	16.17					
sd	2.103014	2.262963	1.567588		25.3	23.103	88	67.455
se	0.66	0.71	0.49		8.260347	2.126474	10.32796	12.06705
					2.61	0.67	3.26	3.81
LA GROUP								
10	11.4	13.6	16.15	m	24	24.62	36	78.2
12	7.8	8	14.5	m	17	23	24	70.4
19	12.1	12.65	15.05	m	32	23.37	24	72.4
9	6.95	10.05	13.85	m	31	24.48	36	75.4
6	7.95	9.5	14.1	m	27	23.85	40	79.9
1	13.25	13.3	18.3	f	30	23.14	32	63.8
7	12	12.95	15.55	f	18	23.32	16	69
16	7	9	14.05	f	18	18.9	36	54
8	7	8.6	13	f	23	21.85	36	50.5
18	6.5	8.1	11.2	f	35	25.03	16	71.1
mean	9.195	10.575	14.575		25.5	23.156	29.6	68.47
sd	2.646743	2.287435	1.898428		6.485025	1.757721	8.884443	9.740072
se	0.83	0.72	0.59		2.04	0.55	2.81	3.08

		Overall	RPE At	2.0, 2.5 And 4.0mM HLa				
HA GROUP								
subject	2.0mM	2.5mM	4.0mM	gender	age	bmi	q score	mass
13	10.75	12.25	15.45	m	23	22.84	80	82
17	10	14.4	16	m	17	23.12	100	70.3
5	12.33	16	17.95	m	33	22.04	100	69
4	11.55	12	15.28	m	20	24.34	100	73.7
2	11.1	12.35	15.85	m	21	27.75	80	85
11	11	11.5	17.1	f	37	22.64	100	53
15	12.4	13.5	17.9	f	19	24.49	80	75.7
20	10.4	11.15	13.4	f	19	19.72	80	55
3	7.5	8	13.5	f	24	21.52	80	58.6
14	10	11	15.35	f	40	22.57	80	52.25
mean	10.703	12.215	15.778		25.3	23.103	88	67.455
sd	1.407591	2.152653	1.577817		8.260347	2.126474	10.32796	12.06705
se	0.44	0.68	0.5		2.61	0.67	3.26	3.81
LA GROUP								
10	11.8	12.65	14.95	m	24	24.62	36	78.2
12	6.8	8	14.33	m	17	23	24	70.4
19	12.15	12.75	14.15	m	32	23.37	24	72.4
9	6.95	9.77	12.55	m	31	24.48	36	75.4
6	7.2	9.4	14	m	27	23.85	40	79.9
1	13.25	14.75	17.95	f	30	23.14	32	63.8
7	12	12.85	15.6	f	18	23.32	16	69
16	7	9.25	13.4	f	18	18.9	36	54
8	7	8.6	12.65	f	23	21.85	36	50.5
18	6.5	9.25	11.25	f	35	25.03	16	71.1
mean	9.065	10.727	14.083		25.5	23.156	29.6	68.47
sd	2.814945	2.296921	1.855173		6.485025	1.757721	8.884443	9.740072
se	0.88	0.72	0.58		2.04	0.55	2.81	3.08

Activity Questionaire scores for HA and LA

HA GROUP	
subject	Score
13	80
17	100
5	100
4	100
2	80
11	100
15	80
20	80
3	80
14	80
mean	88
sd	10.32796
se	3.26

LA GROUP	
10	36
12	24
19	24
9	36
6	40
1	32
7	16
16	36
8	36
18	16
mean	29.6
sd	8.884443
se	2.8

Estimated VO2 max for HA andLA

HA GROUP	
subject	VO2
13	65
17	59.7
5	62.3
4	48.85
2	50
11	72.6
15	35
20	36.36
3	48.63
14	50.71
mean	52.915
sd	12.06888
se	3.81

LA GROUP	
10	40.28
12	46.87
19	51.79
9	33.15
6	42.8
1	68.8
7	33.3
16	37.9
8	37.6
18	37.2
mean	42.969
sd	10.77668
se	3.41

APPENDIX K

Raw Data

* * * * * * Analysis of Variance -- design 1 * * * * *

Tests of Between-Subjects Effects.

WORKLOAD

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	108525.00	18	6029.17		
GROUP	49651.27	1	49651.27	8.24	.010

* * * * * * Analysis of Variance -- design 1 * * * * *

Tests of Between-Subjects Effects.

HEART RATE

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	5648.17	18	313.79		
GROUP	2522.02	1	2522.02	8.04	.011

* * * * * * Analysis of Variance -- design 1 * * * * * *

Tests of Between-Subjects Effects.

CENTRAL RPE

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	165.75	18	9.21		
GROUP	54.44	1	54.44	5.91	.026

* * * * * * Analysis of Variance -- design 1 * * * * * *

Tests of Between-Subjects Effects.

LOCAL RPE

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	216.22	18	12.01		
GROUP	46.03	1	46.03	3.83	.066

* * * * * * Analysis of Variance -- design 1 * * * * * *

Tests of Between-Subjects Effects:

OVERALL RPE

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	199.61	18	11.09		
GROUP	38.74	1	38.74	3.49	.078

Independent groups t test

X (groups):	w/load
Y (dependent variable):	2.0

Groups	Count	Means	Std. Devs.
high	10	106.200	42.397
low	10	55.800	32.809

t_{obt}	df	p_2 tail	p_1 tail
2.973	18	0.00815	0.00407

Independent groups t test

X (groups):	w/load
Y (dependent variable):	2.5

Groups	Count	Means	Std. Devs.
high	10	136.200	60.758
low	10	78.800	31.148

t_{obt}	df	p_2 tail	p_1 tail
2.659	18	0.01600	0.00800

Independent groups t test

X (groups):	w/load
Y (dependent variable):	4.0

Groups	Count	Means	Std. Devs.
high	10	178.500	67.011
low	10	113.700	37.008

t_{obt}	df	p_2 tail	p_1 tail
2.677	18	0.01539	0.00769

HEART RATE

Independent groups t test

X (groups):	hrhla2.0
Y (dependent variable):	Column 2

Groups	Count	Means	Std. Devs.
high	10	116.300	20.309
low	10	103.900	9.574

t_{obt}	df	p_2 tail	p_1 tail
1.746	18	0.09777	0.04889

Independent groups t test

X (groups):	2.5
Y (dependent variable):	Column 3

Groups	Count	Means	Std. Devs.
high	10	131.000	12.667
low	10	118.100	10.071

t_{obt}	df	p_2 tail	p_1 tail
2.521	18	0.02136	0.01068

Independent groups t test

X (groups):	4.0
Y (dependent variable):	Column 4

Groups	Count	Means	Std. Devs.
high	10	156.500	7.605
low	10	142.900	9.291

t_{obt}	df	p_2 tail	p_1 tail
3.582	18	0.00213	0.00107

CENTRAL RPE:

Independent groups t test

X (groups):	rpeC2.0
Y (dependent variable):	Column 2

Groups	Count	Means	Std. Devs.
highc2	10	10.480	2.161
lowc2	10	8.630	2.173

t_{obt}	df	p_2 tail	p_1 tail
1.909	18	0.07236	0.03618

Independent groups t test

X (groups):	2.5
Y (dependent variable):	Column 11

Groups	Count	Means	Std. Devs.
high	10	12.020	2.004
low	10	10.110	1.976

t_{obt}	df	p_2 tail	p_1 tail
2.146	18	0.04573	0.02286

Independent groups t test

X (groups):	4.0
Y (dependent variable):	Column 12

Groups	Count	Means	Std. Devs.
high	10	15.155	1.577
low	10	13.200	1.536

t_{obt}	df	p_2 tail	p_1 tail
2.808	18	0.01163	0.00581

Independent groups t test

X (groups):	vo2
Y (dependent variable):	Column 2

Groups	Count	Means	Std. Devs.
high	10	52.915	12.069
low	10	42.969	10.777

t_{obt}	df	$p_{2\ tail}$	$p_{1\ tail}$
1.944	18	0.06771	0.03386

Independent groups t test

X (groups):	question
Y (dependent variable):	Column 2

Groups	Count	Means	Std. Devs.
high	10	88.000	10.328
low	10	29.600	8.884

t_{obt}	df	$p_{2\ tail}$	$p_{1\ tail}$
13.556	18	0.00000	0.00000

W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	87	1.6	6	6	6			
40	94	1.6	6	6	6			
90	101	1.8	8	8	8			
140	110	2.1	9	9	10	no 13	male	HA
165	119	1.7	10	10	10			
190	126	2.1	12	11	11			
240	139	2.8	13	13	13			
265	153	3.7	15	15	15			
290	159	5.9	16	17	17			
40	115	5.2	6	6	6			
40	102	4.4	6	6	6			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	57	2.6	6	6	6			
90	93	2	8	8	8			
140	117	2.1	11	11	12	no 17	male	HA
190	135	2.4	13	13	14			
215	145	2.9	15	14	16			
240	160	3.6	16	17	16			
265	169	4.7	17	18	16			
90	117	4.2	10	11	10			
90	107	2.4	8	9	8			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	46	1.7	6	6	6			
40	70	1.3	8	8	8			
65	79	1.5	11	12	12			
90	94	1.4	12	12	12	no:5	male	HA
115	104	1.2	13	13	13			
140	117	1.4	13	13	13			
165	131	1.9	14	15	14			
190	144	2.5	16	17	16			
215	150	3	16	17	17			
240	155	4.3	18	19	18			
40	93	3.4	9	10	9			
40	87	3	6	7	6			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	80	1.7	6	6	6			
90	113	1.3	7	7	7			
140	121	1.8	10	10	10			
190	144	2.5	12	13	12	no 4	male	HA
240	168	3.7	14	15	15			
265	181	5.3	16	16	16			
90	132	4	9	8	8			
90	132	2.9	8	8	8			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	71	2.3	6	6	6			
65	95	2.1	7	7	7			
90	99	1.4	8	8	8			
115	110	1.2	9	10	10	no 2	male	HA
140	120	2.2	11	12	12			
165	126	4.1	13	14	14			
190	142	3.4	14	15	15			
215	150	4.1	15	16	16			
240	156	4.8	16	17	17			
65	117	4.7	11	11	11			
65	114	3.6	9	10	10			

65	114	3.6	9	10	10			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	65	2.2	6	6	6			
40	84	2.4	6	6	6			
65	103	2	8	8	8			
90	117	1.7	11	11	10			
115	124	2	12	11	11			
140	136	2.9	13	13	12	no 11	female	HA
165	150	3.4	15	17	16			
190	162	6.1	19	19	20			
40	107	5.3	7	7	7			
40	100	3.9	6	6	6			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	82	1.7	6	6	6			
40	98	1.7	7	7	7			
65	121	1.5	11	10	11			
90	136	2.5	13	14	13.5	no 15	female	HA
115	152	3.4	16	17	17			
140	168	4.9	18	19	19			
40	125	4.5	11	13	12			
40	118	3.7	8	11	10			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	83	1	6	6	6			
40	126	1.8	9	11	10	no 20	female	HA
65	151	3.7	12	15	13			
90	174	6.1	15	17	16			
40	147	5.6	11	10	10			
40	145	5.1	10	10	10			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	63	1.9	6	6	6			
40	81	2.4	6	6	6			
90	109	2.6	11	9	11			
115	130	3.4	12	12	12	no 3	female	HA
140	155	4.2	14	14	14			
165	172	6.9	16	16	16			
40	117	7.2	7	6	7			
40	106	5.4	7	6	7			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	75	3	6	6	6			
40	95	2.7	6	6	6			
65	119	3.1	8	9	8			
90	130	2.5	10	11	11			
115	153	3.4	13	14	14	no 14	female	HA
140	168	4.3	15	16	16			
165	173	7	17	17	17			
40	128	8.2	7	7	7			

W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	81	0.9	6	6	6			
40	108	2.2	7	7	7			
65	119	2.2	8	9	9	no 9	male	LA
90	131	3.3	12	13	12			
115	153	5	14	15	15			
140	172	7.1	16	17	17			
40	134	7.1	11	11	11			
40	123	6.2	7	9	8			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	73	1.7	6	6	6			
40	89	1.7	6	7	6			
65	99	2.4	9	9	9			
90	115	2.8	11	11	11			
115	127	3.1	12	13	12	no 6	male	LA
140	137	3	12	13	13			
165	145	4.8	15	15	15			
190	158	7.3	16	17	16			
40	122	6.7	10	11	11			
40	114	6.2	10	10	10			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	53	1.4	6	6	6			
40	87	1.3	7	8	7			
65	94	1.5	10	11	11			
90	104	1.9	6	13	6			
115	120	3.3	14	17	17	no 1	female	LA
140	133	4.4	15	19	19			
40	91	4.7	7	7	7			
40	88	3.8	7	7	7			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	84	1.7	6	6	6			
40	105	1.7	7	7	7			
65	128	2	11	12	12			
90	148	3.6	15	15	15			
115	168	5.6	17	18	18	no 7	female	LA
40	142	5.8	11	10	10			
40	135	4.7	8	7	7			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	81	1.6	6	6	6			
40	110	2	8	7	7			
65	141	2.9	10	11	11	no 16	female	LA
90	164	4.3	12	15	14			
115	178	7.2	15	17	16			
40	140		9	10	9			
40	129	5.9	8	8	8			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	87	1.7	6	6	6			
40	113	2.3	8	8	8	no 8	female	LA
65	145	4.1	12	13	13			
90	169	7.8	17	17	17			
40	151	6.7	13	14	14			
40	141	6.2	12	12	12			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	92	1.9	6	6	6			
40	115	2.1	7	7	7	no 18	female	LA
65	140	3.5	10	11	11			
90	172	6.2	12	12	12			
115	185	7.5	16	15	15			
40	147	9.3	12	11	11			
40	150	9.9	9	9	9			

W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	79	1.4	6	6	6			
40	78	1.5	7	8	7			
65	84	1.4	9	10	9	no 10	male	LA
90	101	2.3	11	12	11			
115	115	2.1	12	13	12			
140	139	3.3	13	15	14			
165	154	4.5	15	17	16			
190	168	6	16	19	17			
40	121	6.6	12	13	12			
40	112	4.8	9	10	9			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	71	2.8	6	6	6			
40	94	1.7	6	7	6			
65	104	2.5	8	8	8	no 12	male	LA
90	112	3	9	11	10			
115	129	3.7	14	14	14			
140	142	5.1	15	16	16			
40	104	4.7	14	14	14			
40	102	3	11	12	11			
W/load	H/rate	HLa	RPE Cent	RPE Loc.	RPE O/all	Subject No	Gender	Group
0	68	1.4	6	6	6			
40	70	1.5	9	9	9			
65	80	1.2	10	11	11	no 19	male	LA
90	91	1.5	11	12	11			
115	105	1.9	11	12	12			
140	118	2.7	12	13	13			
165	138	3.9	13	15	14			
190	151	6.3	17	16	17			
40	95	5.7	9	10	9			
40	97	4.5	8	9	8			

APPENDIX L

Test-Retest Data

Reliability Test One

w/load	h/rate	HLa	rpe C	rpeL	rpe O	
0	46	1.7	6	6	6	
40	70	1.3	8	8	8	
65	79	1.5	11	12	12	
90	94	1.4	12	12	12	
115	104	1.2	13	13	13	
140	117	1.4	13	13	13	test 1
165	131	1.9	14	15	14	
190	144	2.5	16	17	16	
215	150	3	16	17	17	
240	155	4.3	18	19	18	
40	93	3.4	9	10	9	
40	87	3	6	7	6	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	53	1.4	6	6	6	
40	87	1.3	7	8	7	
65	94	1.5	10	11	11	
90	104	1.9	12	13	13	
115	120	3.3	14	17	17	test 1
140	133	4.4	15	19	19	
40	91	4.7	7	7	7	
40	88	3.8	7	7	7	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	81	0.9	6	6	6	
40	108	2.2	7	7	7	
65	119	2.2	8	9	9	
90	131	3.3	12	13	12	test 1
115	153	5	14	15	15	
140	172	7.1	16	17	17	
40	134	7.1	11	11	11	
40	123	6.2	7	9	8	

w/load	h/rate	HLa	rpe C	rpe L	rpe O	
0	74	1.5	6	6	6	
40	86	1.5	7	7	7	
90	101	2.3	10	11	11	
140	119	2.8	11	12	12	
165	131	3.8	13	15	14	test 1
190	146	4.9	15	17	16	
215	162	8.9	18	19	19	
40	112	8	11	12	12	
40	102	6.2	8	9	8	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	65	2.2	6	6	6	
40	84	2.4	6	6	6	
65	103	2	8	8	8	
90	117	1.7	11	11	10	
115	124	2	12	11	11	
140	136	2.9	13	13	12	test 1
165	150	3.4	15	17	16	
190	162	6.1	19	19	20	
40	107	5.3	7	7	7	
40	100	3.9	6	6	6	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	68	1.4	6	6	6	
40	70	1.5	9	9	9	
65	80	1.2	10	11	11	test 1
90	91	1.5	11	12	11	
115	105	1.9	11	12	12	
140	118	2.7	12	13	13	
165	138	3.9	13	15	14	
190	151	6.3	17	16	17	
40	95	5.7	9	10	9	
40	97	4.5	8	9	8	

Reliability Test two

w/load	h/rate	HLa	rpe C	rpeL	rpe O	
0	53	1.4	6	6	6	
40	70	1.7	7	7	7	
65	77	1.5	8	9	8	
90	85	1.3	11	11	10	
115	98	1.5	12	12	12	
140	106	1.4	12	12	12	
165	121	1.7	13	13	13	
190	135	2.8	15	15	15	
215	145	3	16	17	17	test 2
240	155	4.1	18	18	18	
40	101	3.7	11	11	11	
40	88	3	7	8	7	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	56	1.7	6	6	6	
40	85	1.6	7	7	7	
65	101	1.6	9	10	10	
90	111	2.4	10	12	11	
115	125	3.8	12	14	14	test 2
140	140	5.2	14	17	17	
40	94	5.4	6	6	6	
40	85	4.3	6	6	6	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	86	0.9	6	6	6	
40	105	1.6	6	7	7	
65	114	1.9	7	9	8	
90	133	3.9	11	13	12	test 2
115	153	4.5	13	15	14	
140	168	6.7	17	19	18	
40	121	7.2	13	15	13	
40	115	5.2	11	12	11	

w/load	h/rate	HLa	rpe C	rpe L	rpe O	
0	63	1.6	6	6	6	
40	76	1.7	8	8	8	
90	98	2	10	10	10	
140	112	3.3	11	12	12	
165	129	4.1	13	14	14	test 2
190	142	5.2	15	17	16	
215	155	8.2	17	19	19	
40	105	6	10	11	10	
40	99	5.2	7	9	8	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	73	1.8	6	6	6	
40	94	1.6	6	6	6	
65	108	1.8	7	7	7	
90	115	1.8	10	10	10	
115	129	2.3	11	12	12	
140	144	2.7	13	13	14	
165	153	4.3	16	15	16	test 2
190	163	7.2	19	19	19	
40	111	5.9	6	6	6	
40	111	4.3	6	6	6	

w/load	h/rate	HLa	rpeC	rpeL	rpeO	
0	59	1.3	6	6	6	
40	74	1.4	9	9	9	
65	78	1.5	9	11	9	
90	91	1.6	10	12	10	test 2
115	100	1.9	11	12	11	
140	115	3.1	11	13	12	
165	133	4.6	12	15	13	
190	150	5.8	13	16	14	
40	96	5.6	9	10	9	
40	95	3.9	8	9	8	

RPE Central test re-test at 2.0, 2.5 and 4.0mM			
rpeC 2.0			
subject	test1	test2	diff
1	12.2	9.5	2.7
3	8.9	10	-1.1
5	14.45	13.5	0.95
9	7.1	7.5	-0.4
19	11.1	11.1	0
mean	10.75	10.32	0.43
sd	2.857446	2.204994	1.469524
se			0.65
ME			1.03
V			9..80%
rpeC 2.5			
subject	test1	test2	diff
3	10.4	10.45	0.05
5	16	14.4	1.6
9	9.05	8.25	0.8
11	12.6	12	0.6
19	11.75	11	0.75
mean	11.96	11.22	0.76
sd	2.630447	2.246275	0.556103
se			0.24
ME			0..39
V			3.30%
rpeC4.0			
subject	test1	test2	diff
1	14.6	14	0.6
3	13.4	12.75	0.65
5	17.6	17.25	0.35
9	12.8	11.3	1.5
11	15.9	15.4	0.5
19	13.2	11.6	1.6
mean	14.58333	13.71667	0.866667
sd	1.86163	2.308824	0.540062
se			0.24
ME			0.38
V			2.70%

RPE Local test re-test at 2.0, 2.5 and 4.0mM

rpeL 2.0

subject	test1	test2	diff
1	13.25	11	2.25
3	9.5	10	-0.5
5	15.4	13.5	1.9
9	6.95	9.25	-2.3
11	11	10.8	0.2
19	12.1	12.1	0
mean	11.36667	11.10833	0.258333
sd	2.948842	1.516053	1.664457
se			0.67
ME			1..17
V			10.40%

rpeL2.5

subject	test1	test2	diff
1	13.3	12.1	1.2
3	11.45	10.85	0.6
9	10.05	10.25	-0.2
11	12.1	12.5	-0.4
19	12.65	12.5	0.6
mean	11.91	11.64	0.36
sd	1.243684	1.030413	0.654217
se			0.29
ME			0.46
V			3.90%

rpeL 4.0

subject	test1	test2	diff
1	18.3	17	1.3
3	15.4	13.75	1.65
5	18.55	17.75	0.8
9	13.85	13.35	0.5
19	15.05	14.2	0.85
mean	16.23	15.21	1.02
sd	2.086444	2.016618	0.453597
se			0.2
ME			0.32
V			2.03%

RPE Overall test re-test at 2.0, 2.5 and 4.0mM

rpeO 2.0

subject	test1	test2	diff
1	13.25	10.2	3.05
3	9.45	10	-0.55
5	12.33	13.5	-1.17
9	6.95	8.1	-1.15
11	11	10.8	0.2
19	12.15	11.1	1.05
mean	10.855	10.61667	0.238333
sd	2.316582	1.758882	1.618523
se			0.65
ME			1.13
V			10.60%

rpeO 2.5

subject	test1	test2	diff
3	11.4	10.85	0.55
5	16	14.4	1.6
9	9.77	9.2	0.57
11	11.5	13	-1.5
19	12.75	11.5	1.25
mean	12.284	11.79	0.494
sd	2.331422	1.996998	1.202052
se			0.53
ME			0.84
V			7.00%

rpeO4.0

subject	test1	test2	diff
1	17.95	17	0.95
3	14.4	13.75	0.65
5	17.95	17.95	0
9	12.55	12.4	0.15
11	17.1	15.55	1.55
19	14.15	13.55	0.6
mean	15.68333	15.03333	0.65
sd	2.284659	2.164409	0.561249
se			0.22
ME			0.39
V			2.50%

Heart Rate test re-test at 2.0, 2.5 and 4.0mM

H/R 2.0mM

subject	test1	test2	diff
1	105	107	-2
3	98	96	2
5	133	125	8
9	103	115	-12
11	124	120	4
19	106	103	3
mean	111.5	111	0.5
sd	13.75136	10.93618	6.920983
se			2.82
ME			4.89
V			4.40%

H/R 2.5mM

subject	test1	test2	diff
1	112	112	0
3	104	108	-4
5	144	132	12
9	122	120	2
11	131	137	-6
19	115	109	6
mean	121.3333	119.6667	1.666667
sd	14.38981	12.33964	6.623192
se			2.7
ME			4.68
V			3.90%

H/R 4.0mM

subject	test1	test2	diff
1	128	127	1
3	127	134	-7
5	155	154	1
9	140	137	3
11	152	152	0
19	138	126	12
mean	140	138.3333	1.666667
sd	11.71324	12.1106	6.121002
se			2.49
ME			4.32
V			3.10%

W/load test re-test at 2.0, 2.5 and 4.0mM

W/load 2.0

subject	test1	test2	diff
1	92	77	15
3	70	85	-15
5	160	172	-12
9	35	67	-32
11	115	105	10
19	119	118	1
mean	98.5	104	-5.5
sd	43.27008	38.15757	17.53568
se			7.15
ME			12.39
V			12.20%

W/load2.5

subject	test1	test2	diff
1	101	92	9
3	110	110	0
5	190	194	-4
9	75	73	2
11	129	128	1
19	134	129	5
mean	123.1667	121	2.166667
sd	38.99444	41.73248	4.445972
se			1.81
ME			3.14
V			2.60%

W/load 4.0

subject	test1	test2	diff
1	132	118	14
3	170	163	7
5	244	238	6
9	101	95	6
11	171	160	11
19	166	155	11
mean	164	154.8333	9.166667
sd	47.92077	48.88115	3.311596
se			1.35
ME			2.34
V			1.50%

APPENDIX M

Percentiles For Estimated VO_2 max For The Australian Population.

TABLE 15: Estimated $\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$) percentiles

Percentiles	Age 18-29	30-39	40-49	50-59	60-69	70-78
Men						
5	30.7	30.7	25.6	23.1	17.3	——
25	38.8	36.9	32.6	30.1	26.4	——
50	44.3	40.9	37.2	33.6	30.5	——
75	50.5	46.3	43.1	37.6	34.3	——
95	66.5	53.6	53.6	42.4	45.5	——
Mean	*45.5*	*41.5*	*37.9*	*33.6*	*31.1*	*21.5*
Standard deviation	*10.6*	*6.7*	*8.5*	*5.8*	*9.6*	*6.7*
Number of subjects	*85*	*108*	*117*	*80*	*75*	*14*
Women						
5	26.4	21.0	19.5	17.9	16.7	——
25	31.1	25.9	23.5	22.2	21.8	——
50	36.3	31.5	29.0	25.3	25.4	——
75	40.8	38.5	36.1	29.4	31.4	——
95	53.0	47.7	44.3	38.4	64.0	——
Mean	*37.5*	*32.8*	*30.5*	*26.4*	*29.1*	*21.7*
Standard deviation	*10.3*	*8.6*	*9.3*	*6.5*	*14.8*	*6.0*
Number of subjects	*78*	*121*	*106*	*93*	*47*	*10*

Gore, C. & Edwards, D. (1992). Australian Fitness Norms: A Manual for Fitness assessors. Adelaide. The Health Department Foundation

APPENDIX N

Abstract Submitted to American College of Sports Medicine For 1997 Annual Meeting.

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THE USE OF RATINGS OF PERCEIVED EXERTION (RPE) TO ESTIMATE FIXED BLOOD LACTATE CONCENTRATIONS DURING INCREMENTAL CYCLE ERGOMETER EXERCISE.

K.SCOTSON AND P.SACCO.

The aim of this study was to examine differences in the ability of high active (HA) and low active (LA) individuals to utilise RPE to accurately estimate exercise intensities corresponding to 2.0, 2.5 and 4.0mM blood lactate concentration. Subjects (n=20) were matched for age, body mass and gender, placed into experimental groups based on regular physical activity levels, and asked to complete a continuous incremental cycle ergometer protocol consisting of 4 minute stages. At the completion of each workload, heart rate, blood lactate, central, local and overall RPE (Borg 15 point scale) were recorded. ANOVA revealed that despite significant differences between the 2 experimental groups for workload and heart rate ($p<0.05$), no significant differences existed for overall RPE (HA=15.77±0.4, LA=14.08±0.5) at exercise intensities corresponding to 4.0mM blood lactate condition. There was a consistent yet non significant difference between groups for local RPE and a significant difference ($p<0.05$) for central RPE corresponding to 4.0mM blood lactate. The data suggests that differences in the RPE response between groups may only be visible at high relative exercise intensities and that the higher RPE values for HA individuals may be influenced by a combination of relative exercise intensity at which a given blood lactate concentration occurs and the rate of lactate appearance at a given exercise intensity.

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