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The effect of prolonged cycling at the conconi-predicted anaerobic threshold on blood lactate concentrations

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THE EFFECT OF PROLONGED CYCLING AT THE CONCONI-PREDICTED ANAEROBIC THRESHOLD ON BLOOD LACTATE CONCENTRATIONS

BY

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1991

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Date 11-12-92

TO MY FAMILY

ABSTRACT

A study which assessed the validity of the Conconi test to predict the anaerobic threshold (AnT) was undertaken with 20 sport science students. The study involved the subjects undertaking three tests over a one week period. Each test was separated by a period of at least 48 hours which allowed the subjects time to recover. The subjects initially completed a Conconi test which attempted to predict their AnT through plotting heart rate against work intensity. Following the specified recovery, a maximum oxygen uptake test ($\dot{V}O_2max$) was undertaken by all subjects. Following another recovery period those subjects who produced a deflection point in the Conconi test performed a prolonged cycle at the Conconi-predicted AnT. Serial lactate measurements were taken at 5-minute intervals during the prolonged cycle in order to determine whether a steady state lactate response resulted.

Thirty five percent of the subjects failed to produce deflections in the Conconi test. Clinical analysis of the lactate data identified that only 25 % of the remaining subjects produced steady state lactate responses during the prolonged cycle. The findings of the clinical analysis were supported by applying a repeated measures ANOVA to those subjects. All other subjects failed to complete the prolonged cycle and to produce steady state lactate responses. Two subgroups were identified from the subjects who produced deflection points in the Conconi test. A t-test revealed that the two identified subgroups were significantly different. One group deflected at exercise intensities under 85 % $\dot{V}O_2max$ while the other deflected at over 85 % $\dot{V}O_2max$.

Three hypotheses were tested during the study. The first hypothesis stated that the Conconi test would overestimate the anaerobic threshold (AnT), causing blood lactate concentrations to rise continuously in all subjects over the duration of a prolonged cycle at the Conconi-predicted AnT. The second hypothesis stated that each subject's oxygen consumption value measured at the deflection point during the Conconi test would correspond to an intensity greater than 85 % of their $\dot{V}O_2max$. The final hypothesis stated that all subjects would produce a heart rate deflection during execution of the Conconi test.

The three proposed hypotheses were rejected. The results concluded that the Conconi test was an invalid predictor of the AnT. Based on the results of this study the following conclusions were reached: a) the Conconi test will not produce deflection points in all subjects, b) the exercise intensity predicted by the Conconi test will not produce lactate steady state responses in all subjects, and c) the Conconi-Predicted AnT does not correspond to an exercise intensity above 85 % $\dot{V}O_2max$ in all subjects.

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CHAPTER ONE

1. The Problem

The anaerobic threshold (AnT) is the highest exercise intensity possible without an increase in blood lactate levels (Orok, Hughson, Green and Thomson, 1989; McLellan and Jacobs, 1989; Stegmann and Kindermann, 1982). It is used to prescribe optimal training intensities for aerobic endurance type events. Researchers, coaches and athletes have adopted tests of the AnT to supplement the decision making processes involved in designing athletes' periodised training programmes.

Traditional measures of the AnT are problematic in that they involve expensive and sometimes invasive laboratory tests. However, in 1982 Conconi and a group of colleagues developed a non-invasive field test to predict an intensity which corresponded to the AnT (Conconi, Ferrari, Ziglio, Droghetti and Codeca, 1982). This test which was cheap and easy to administer had a reported 0.99 correlation with the AnT when measured by lactate analysis using the procedure of Noll and a Boehringer monotest lactate kit (Conconi et al., 1982). The Conconi test, as it became known, was also adapted for use in a laboratory setting , thus allowing cycle ergometers and treadmills to be utilised (Conconi, Borsetto, Casoni and Ferrari, 1988; Maffulli, Sjodin and Ekblom, 1987). Subsequently, many athletes who designed their training programmes on the basis of Conconi-predicted intensities have enjoyed enormous success at an international level (Cuerdon, 1987).

However, several researchers have questioned the validity of the Conconi test as an accurate predictor of the AnT. In particular problems have arisen with the percentage of maximum oxygen uptake the test predicted, internal validation, and an inability to locate heart rate deflection points. (Francis, McClatchey, Sumsion and Hansen, 1989; Ribeiro, Fielding, Hughes, Black, Bochese and Knutten, 1985; Tokmakidis and Leger, 1988; Van Handel, Baldwin, Puhl, Katz, Dantine and Bradley, 1988).

Measurement of lactate concentrations during prolonged cycling at an exercise intensity corresponding to the Conconi-predicted AnT could help to establish the validity of the Conconi test. To date, no research specific to that mentioned above has been reported in the literature.

2. Purposes of the Study

There is concern among some researchers that the Conconi test does not accurately measure the AnT. It has been suggested that the exercise intensity predicted by the Conconi test occurs significantly higher than the AnT as measured by lactate analysis (Ribeiro et al., 1985; Tokmakidis et al., 1988; Van Handel et al., 1988).

The present study was developed to address the problem of whether the Conconi test accurately measures the AnT. This was achieved through the measurement of blood lactate during prolonged cycling at the Conconi-predicted exercise intensity, and oxygen consumption during execution of the Conconi test.

This study had two purposes. The first was to investigate the effect of prolonged cycling at the Conconi-predicted AnT on blood lactate concentrations, and the second was to quantify the percentage of maximum oxygen uptake the Conconi test predicted.

In this study the following hypotheses were tested:

1. The Conconi test will overestimate the AnT, causing blood lactate concentrations to rise continuously in all subjects over the duration of a prolonged cycle at the Conconi-predicted AnT.

2. Each subject's oxygen consumption value measured at the deflection point during the Conconi test will correspond to an intensity greater than 85 % of their maximum oxygen uptake ($\dot{V}O_2max$).
3. All of the subjects will produce a heart rate deflection during execution of the Conconi test.

3. Significance of the Study

To date, serial measurements of arterialized blood lactate during prolonged exercise at the Conconi-predicted intensity have not been employed. Measurement of this type indicate whether the Conconi test actually predicts an intensity which would give a steady state lactate (SSL). It is known that persons exercising at an intensity corresponding to the AnT will produce a SSL response. Therefore this study provides information relating to whether the Conconi test actually predicts an intensity coincident with the AnT.

Many top calibre athletes have been using the Conconi test to predict the training intensity which corresponded to the AnT. They have assumed that the Conconi test is actually a valid measure of the AnT. The conclusions of this study relating to the Conconi test may be of use to persons considering using the test as a predictor of the AnT.

In addition, oxygen uptake was monitored during execution of the Conconi test. This allowed a percentage of maximum oxygen uptake measure to be obtained at the predicted AnT. These results were then able to be compared to those available in the literature for the traditional tests of the AnT.

4. Delimitations and Limitations

4.1 Delimitations.

1. The study was limited to 20 volunteer subjects, 11 male and nine female, who were derived from a population of 144 sport science students.
2. The study was limited to subjects who cycled at least three times a week on a recreational or competitive basis.

4.2 Limitations.

1. The laboratory used for data collection during the study was not climatically controlled. Dawson (1984) reported that the lactate accumulation of cyclists in hot conditions was greater than in cool conditions. This correlated to a lower AnT in hot conditions. In order to allow for this factor the laboratory temperature was recorded during each test.
2. The food intake of each subject was not monitored the day prior to or the day of each testing session. The body's glycogen stores should be similar prior to each testing session if the results of each are to be compared. All subjects were instructed to consume their 'normal' food intake the day prior to each testing session in order to maintain similar glycogen stores.
3. Exercise external to that involved in the testing was not monitored during the study. All subjects were instructed <u>not</u> to partake in any moderate or intense exercise the morning of the initial testing session and between subsequent testing sessions. This was due to glycogen stores taking up to and greater than 48 hours to be replenished after strenuous exercise (McArdle, Katch and Katch, 1986).
4. Subjects who produced a lactate steady state during the prolonged cycle (Stage 3) were not required to complete any additional cycles at greater intensities. Due to the above conditions it was not possible to ascertain whether the lactate steady state corresponded to a maximal lactate steady state for these subjects.

5. Assumptions

In this study it was assumed that all of the subjects:

a) cycled on a recreational or competitive basis at least three times per week (this criterion was emphasized during the recruiting of volunteers for the study), and

b) followed the instructions concerning food consumption and exercise participation prior to the initial testing session and between subsequent testing sessions.

Note: A glossary of terms which have been used throughout the manuscript has been included as Appendix G.

CHAPTER TWO

Review of Related Literature

1. Introduction

Interest in sport science has increased rapidly over the last decade with many athletes and coaches realising the potential benefits of well designed training programs. The success of such programs can be determined by pre and post testing. The coach, sport scientist and/or athlete can gauge the effectiveness of the program through the use of such measures.

In events of an endurance nature, the traditional measure of an athlete's aerobic power has been the maximal oxygen uptake test. This test measures the athlete's maximal capacity to consume oxygen (Fox, Foss and Bowers, 1989). Since the oxygen system is the predominate energy supplier for endurance activities, it was initially assumed that the higher an athlete's $\dot{V}O_2max$ the better he or she would perform in these types of events. However, a comparison of the $\dot{V}O_2max$ results of elite athletes and their placing in endurance events indicates that this was not always the case. Longhurst and Blundell (1986, p.1) reported that athletes "with lower $\dot{V}O_2max$ values have been able to perform better than those with a higher $\dot{V}O_2max$". They also mention that "individuals with a similar $\dot{V}O_2max$ perform differently in endurance events". It was apparent, however, that all these athletes had $\dot{V}O_2max$ values which were high when compared to the average person.

The AnT was the variable suggested to explain why some athletes with lower $\dot{V}O_2max$ values could perform better than those with higher values. In fact, it has been shown that the AnT has a higher correlation with endurance performance than $\dot{V}O_2max$ (Acevedo and Goldfarb, 1989; Schneider, Lacroix, Atkinson, Troped and Pollack, 1990; Stegmann and Kindermann, 1982).

It has been suggested that the accumulation of lactic acid in the muscles and blood plays a crucial role in determining the success of an athlete in an endurance event (Acevedo et al., 1989). An increase in lactate concentration within the muscle and blood is associated with a feeling of fatigue (Stremel, 1984). The higher that the AnT occurs as a percentage of $\dot{V}O_2max$, the more intensely an individual will be able to exercise before lactic acid will accumulate in his or her body. McLellan (1983) reported that when athletes have similar $\dot{V}O_2max$ values, their performance in endurance events is related to their AnT.

The AnT is the highest exercise intensity that can be maintained without an increase in blood lactate levels (Orok, Hughson, Green and Thomson, 1989; McLellan and Jacobs, 1989; Stegmann and Kindermann, 1982). The AnT, as defined above, has been reported to occur at between 65 % and 90 % of athletes' $\dot{V}O_2max$ by Longhurst and Blundell (1986), between 75 % and 85 % of athletes' $\dot{V}O2max$ by Lopategui, Perez, Smith and Otto (1986), and between 50 % and more than 80 % of athletes' $\dot{V}O_2max$ by Orok et al. (1989). In spite of some discrepancies between researchers it can be seen that the AnT ranges from about 50 % to 90 % of $\dot{V}O_2max$ between athletes. The 50 to 90 % $\dot{V}O_2max$ range for the AnT is seen to be reflective of the state of aerobic training of the individuals tested. Those athletes with a higher state of aerobic training produced results closer to 90 % $\dot{V}O_2max$ while those with results of around 50 % $\dot{V}O_2max$ were representative of a lower aerobically trained state.

In order to design specific training programs that will elevate the AnT to a greater percentage of $\dot{V}O_2max$, it is necessary for the coach and athlete to know what exercise intensity corresponds to the AnT.

2. Determination of the Anaerobic Threshold

At present a variety of tests can be used to determine the AnT. These tests, which can be performed in the laboratory or in the field, may involve gas and / or lactate analysis, heart rate interpretation or a number of demanding workouts at differing power outputs. Each of these methods of AnT determination has its supporters and critics (Conconi et al., 1982; Davis, 1985; Housh, Housh and Bauge, 1990; Wasserman, Hansen, Sue and Whipp, 1987).

The method which is directly related to lactic acid concentrations is that of lactate analysis. Dal Monte (1988) suggests that the only method of establishing the AnT is to perform a series of long exercise bouts, each one at a higher work intensity than the previous one, with blood lactate levels being periodically checked. He suggests that each of the exercise bouts should be at least 30 minutes in duration. Dal Monte considers that the highest exercise intensity that elicits a steady state of lactate over the 30 minute period corresponds to the AnT. This intensity is also known as 'the maximal lactate steady state' (MLaSS) by other researchers (Heck, Mader, Hess, Mucke, Muller and Hollmann, 1985; McLellan et al., 1989; Stegmann et al., 1982). Heck et al. (1985) state that an increase in lactate of less than one millimole (mM) over the last 20 minutes of a 30-minute lactate test is synonymous with MLaSS.

3. Factors Affecting AnT Determination

Accurate determination of the AnT can be affected by warm up, diet and exercise prior to testing (Chwalbinska - Moneta and Hanninen, 1989; Gollnick, Bayly and Hodgson, 1986; Yoshida, 1984). The specificity of tests to various sports also needs to be considered when determining the AnT.

3.1 Warm Up.

McArdle, Katch and Katch (1986, p. 412) report that "there is little concrete evidence that warming up per se directly affects subsequent exercise performance". However they also state, "that is not to say that warming up is unimportant for such purposes" (P. 412). McArdle et al. (1986) and Fox, Bowers and Foss, (1989) mention ,among other factors, that a possible positive effect on subsequent performance after warming up may be due to increased blood flow and oxygen availability.

Chwalbinska-Moneta and Hanninen (1989) concluded in their study, that warming up prior to exercise increased the AnT and the individual anaerobic threshold (IAT). They suggested that warming up probably promoted an earlier onset of sweating, which may have attenuated hyperthermia. This may have indirectly affected the anaerobic threshold in a positive sense, as increased muscle or body temperature is associated with elevated blood lactate levels (Chwalbinska-Moneta, 1989; Fox et al., 1989; McArdle et al., 1986).

The use of a warm up prior to incremental tests of the AnT is common-place amongst researchers world wide (Chwalbinska-Moneta et al., 1989; Haverty, Kenney and Hodgson, 1988; Withers, Sherman, Miller and Costill, 1981; Yoshida, 1984a). A 4-minute warm up was used by all the above researchers with the exception of Chwalbinska et al (1989) who used one of a 10-minute duration.

In the athletic community warm ups of up to 30 minutes duration are commonly undertaken. The length of the warm up seems to be dependant upon the type of event and subjective feelings of the athlete. At this stage there is a paucity of research dealing with the optimal length of the warm up period prior to testing. Whether it should be specific in length to the warm up normally used by the athlete is unclear.

All of the studies reviewed, which included a warm up prior to AnT testing, employed submaximal work loads during the warm up period. In addition the work loads used for warming up in all the tests were less than those of the subsequent AnT.

In summary, although there is only one study which has directly assessed the affect of warm up on the subsequent AnT evaluation, most researchers have adopted one as part of their testing protocol. Since the only study in this area has shown a positive effect on the AnT, it seems appropriate to include one in the testing protocol. In addition the inclusion of a warm up will make the present study more methodologically comparable to previous studies.

3.2 Prior Exercise.

When an athlete exercises, fuel is needed to power the muscles. The type of fuel used depends upon the length and intensity of the exercise undertaken (Sherman, 1987). Fat, in the form of free fatty acids, and carbohydrates, in the form of glycogen and blood-bourne glucose, are the main sources of fuel the body uses during exercise (Wooton, 1989).

Exercise performed in steady state conditions utilises a mixture of carbohydrates and fats. The majority of energy produced in the beginning of this type of exercise comes from carbohydrate sources, with fats providing greater amounts as the exercise progresses (McArdle et al., 1986). In this type of exercise glycogen stores are depleted quite slowly, with up to 50 % or more remaining after one hour. In non steady state conditions when oxidative metabolism alone cannot supply the energy (ATP) needed for exercise, glycogen stores are depleted at a faster rate (Wooton, 1989).

If the exercise performed is of steady state for up to or over one hour, or non steady state for moderate periods of time, significant amounts of glycogen (up to 50 % or more) can be depleted. If the intensity or duration of the exercise is of a large magnitude, and glycogen stores are severely depleted, then it may take 48 hours or more to replenish them on a high (70 %) carbohydrate diet (McArdle et al.,1986).

Studies have shown that low levels of muscle glycogen are associated with lower levels of lactate accumulation in the blood during exercise (Foster, Snyder, Thompson and Kuettel, 1988; Yoshida, 1984a). Due to this response the exercise intensity required to elicit a 4 mM lactate level was greater than when the glycogen stores were high (Foster et al., 1985; Yoshida, 1984a). Neary and Wenger (1985) found that the work intensity ($\dot{V}O_2$) at the AnT was increased in a group of subjects who performed endurance exercise 24 hours prior to being tested.

The above mentioned studies may be easily misinterpreted as suggesting that low levels of muscle and liver glycogen have a positive effect on the AnT, and hence endurance performance. In fact, in endurance events glycogen is the major source of energy and therefore large quantities in the muscles and liver are desirable (Hargreaves, 1987; Sherman, 1987). Instead, the above mentioned studies are suggesting that low levels of muscle and liver glycogen may cause an overestimation of the AnT.

In summary, it has been shown that (a) moderate duration high intensity or long duration lower intensity exercise lowers the muscle glycogen stores, (b) it can take up to 48 hours or more to replenish severely depleted glygogen stores, and (c) the AnT can be overestimated when the glycogen stores are low. Therefore exercise performed up to 24 hours or more prior to testing may cause an overestimation of the AnT. This was supported by Neary et al. (1985).

3.3 Diet.

Most of the carbohydrates which are consumed in the diet are stored as glycogen in the muscles and liver (Wooton, 1989). From the preceding discussion it can be seen that low glycogen levels may affect the accurate evaluation of the AnT. Because most athletes train frequently, (several times a day now being common), the stores of glycogen are depleted and must be replaced if optimal performance is desired.

If the carbohydrate consumed throughout the course of the day is inadequate to replace the depletion of glycogen, then the glycogen stores in the liver and muscle will be reduced with subsequent exercise and the athlete's performance will suffer. It is suggested that an athlete should consume between 50 and 60 % of their daily calories as carbohydrates (Wooton, 1989). Although there is no difference between consuming simple (e.g. fizzy drinks, snack foods) or complex carbohydrates (e.g. pasta, potatoes) on glycogen replenishment in the first 24 hours, during the following 24 hours glycogen replenishment is enhanced by consuming complex sources (O'Connor, 1991; McArdle et al., 1986).

In a study conducted by Yoshida (1984a) it was found that a diet low in carbohydrate significantly affected onset of blood lactate accumulation (OBLA) but had no affect on lactate threshold (LT). The work intensity ($\dot{V}O_2$) was significantly higher at OBLA with a diet low in carbohydrates.

3.4 Specificity.

It has been long suggested that athletes should train in an environment specific to the one in which they will compete. Fox et al. (1989) report that many studies have shown that the $\dot{V}O_2max$ of athletes is greater when tested in the activity in which they trained. They suggest that this is probably due to the more efficient utilisation of the muscle groups employed.

Withers et al. (1981) conducted a study involving two groups of athletes to observe whether specificity of testing affected the AnT. One group of cyclists and one group of runners had their AnTs evaluated on both the treadmill and the cycle ergometer. The data revealed that runners achieved significantly greater AnT's than cyclists when tested on the treadmill, whereas the cyclists achieved higher results than runners when tested on the cycle ergometer. The results of the study add support to the recommended practice of conducting determinations of the AnT in a mode specific to that of which an athlete trains.

3.5 Standardisation of Testing

One of the major purposes of conducting testing sessions is to collect information on the subjects which can be used as baseline data. Information collected in subsequent testing sessions is then compared to the baseline data in order to determine whether any progress is being made. Training modifications that are instigated by the coach are based, in part, on any differences that arise during these comparisons (Rushall and Pyke, 1990).

With such a heavy emphasis placed upon the differences between the pre and post tests, it is important that the measured differences are directly related to the athlete's training. In reality it is often difficult to ensure that the subject will not be affected by some external factor(s) during the testing sessions. These external factors, which have the possibility of contaminating the test results, can be controlled for, to a large degree, through standardised testing programs (Minikin, 1991).

Standardisation dictates that the conditions leading up to testing sessions which are to be compared should be as similar as possible. In addition, it also dictates that the conduct of the actual testing sessions should be replicated if comparable results are desired. As with other testing programs, those which endeavour to determine the

AnT must also be standardised. Some of the key considerations which warrant mention are as follows:

1. Try to ensure that the subject's food consumption in the days leading up to each testing session are similar.
2. Ensure that the athlete does not exercise on the day of the test and, if possible no more than a light session should be conducted on the day preceding it.
3. The tests should be conducted at the same period of a macro and microcycle (e.g. If testing occurred during Day 3 of the fourth week of a macrocycle initially then it should be replicated during the retest).
4. Each subsequent testing session should be conducted at the same time of the day as its predecessor.
5. The order in which the tests are conducted during each session should be replicated during subsequent sessions.
6. If possible the temperature and relative humidity of the testing site should be replicated.

4. The Conconi Test

The inherent problem with using gas and lactate analysis methods of detecting the AnT is that they are often prohibitively expensive for the athlete and require the use of elaborate equipment. In addition, the use of lactate analysis involves the invasive procedure of blood sampling. Many athletes may refuse to be tested because they are afraid of contracting the HIV virus.

What the coach and athlete need is a simple test of the AnT which can be conducted in the laboratory or field with minimal equipment and expense. In 1982 Conconi et al. presented a test which they had designed to accomplish this task. The test, known simply as the Conconi test, used work intensity and heart rate to predict the AnT.

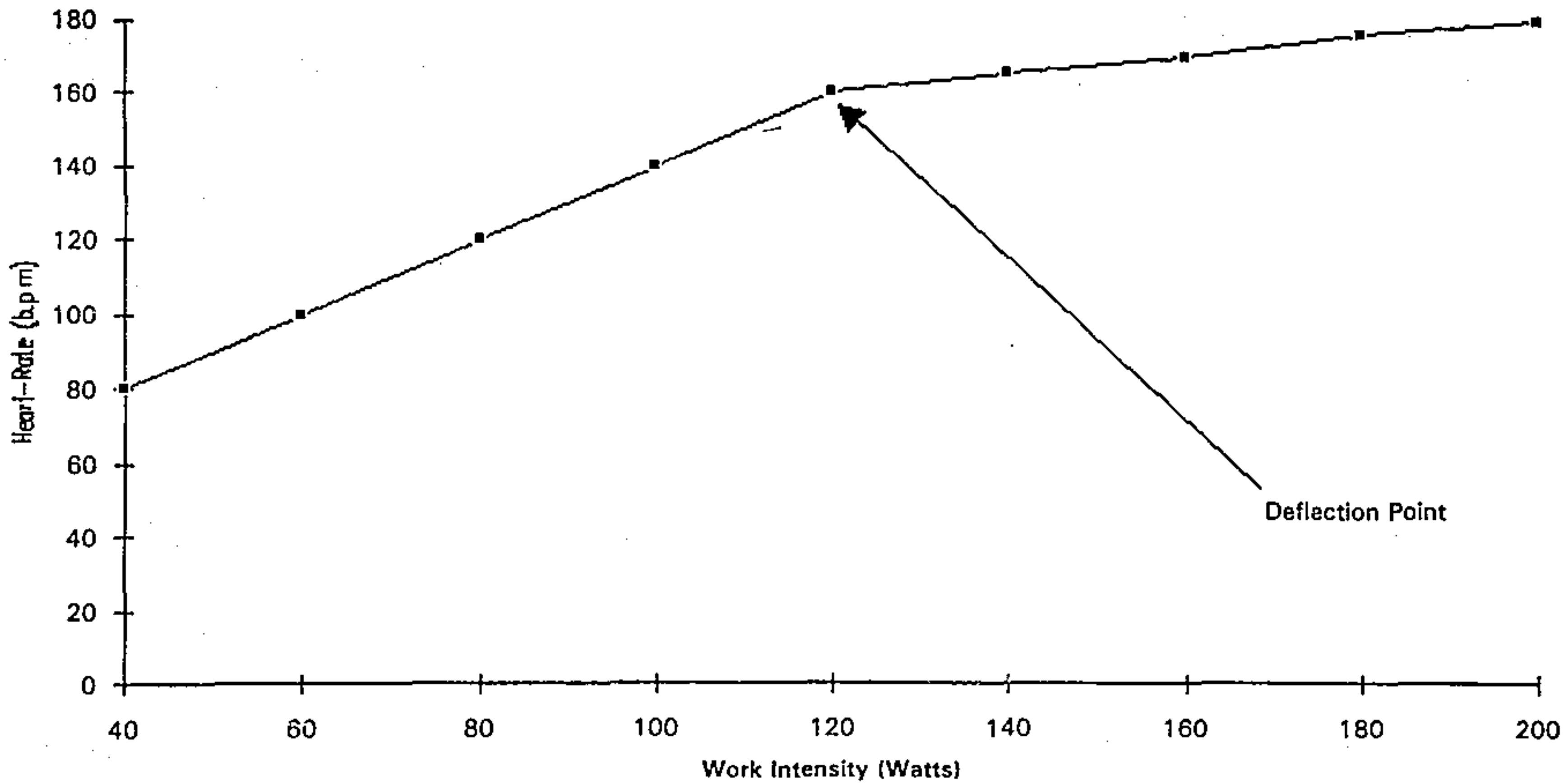
The original Conconi test was designed to be administered to the athlete in the field (Conconi et al., 1982), but Conconi and others have since applied the same methodology to laboratory testing (Brettoni, Alessandri, Cupelli, Bonifazi and Martelli, 1989; Conconi, Borsetto, Casoni and Ferrari, 1988; Maffuli, Sjodin and Ekblom, 1987). An extension of this test has also been designed involving the use of a wind trainer in the home (Argentieri, Ennis and Piper, 1988).

In the Conconi test the subject commences exercise at a low intensity followed by small increments each minute until exhaustion occurs. Exhaustion is deemed to occur when the subject can no longer maintain the set intensity for a period of at least 20 seconds. Heart rate is recorded immediately before the test begins and at the end of each minute during the test. Upon completing the test the work intensity and heart rate are plotted, with work intensity on the 'X' axis and heart rate on the 'Y' axis. Upon examining the resulting graph, a linear relationship is evident between work intensity and heart rate up to a deflection point. Above this deflection point either the relationship becomes curvilinear or the gradient of the slope decreases (see Figure 1). The work intensity or heart rate corresponding to this deflection point is taken to represent the AnT (Conconi et al., 1982, 1988).

4.1. Validity of the Conconi Test

Conconi et al. (1982, 1988) and various other researchers report that the Conconi test correlates highly with the AnT as determined by lactate analysis (Droghetti, 1986; Maffulli et al., 1987). Correlations of 0.99 between the Conconi test and AnT (lactate analysis) have been found in running (Conconi et al., 1982, 1988), cycling (Droghetti et al., 1985, Maffulli et al., 1987) and rowing (Droghetti et al., 1985; Droghetti, 1986). Cellini et al. (1986) found a correlation of 0.84 between the Conconi test and lactate analysis when testing swimmers.

Figure 1. Hypothetical Example of a Graphed Conconi Test



4.2. Reliability of the Conconi Test

Cellini et al. (1986) and Conconi et al. (1982) have performed tests in order to determine the test-retest reliability of the Conconi test. Cellini et al. (1986) tested nine pent-athletes and found a test-retest correlation of 0.99. Conconi et al. (1982) conducted a similar test on 26 athletes and found an identical reliability correlation of 0.99. In the Cellini study the athletes were retested three days after their initial test. Conconi et al. (1982) retested their athletes within one week of the initial test.

Brettoni et al. (1989) conducted a study involving 21 athletes to determine the correlation between Conconi tests in the field and in the laboratory. The resulting correlations were 0.85 for running speeds, 0.89 for running heart rates and 0.96 for cycling heart rates at the Conconi deflection point. These high correlations which were all significant at 0.01 suggest that laboratory Conconi test results can be generalized to the field.

4.3. Problems With the Conconi Test

Although the Conconi test has gained support from some groups of researchers, it has also been the target of much criticism from others (Francis et al., 1989; Ribeiro et al., 1985; Van Handel et al., 1988; Tokmakidis et al., 1988). Tokmakidis et al. (1988) failed to confirm the high correlation between the Conconi test and lactate analysis of the AnT reported in other studies. A heart rate (intensity) deflection point was considered impossible to locate in 9 % of cases and was considered doubtful in 36 %. Similar problems were experienced by Ribeiro et al. (1985) when 50 % of their subjects failed to produce a deflection point in heart rate. Francis et al. (1989) warned against using heart rate as an indicator when 100 % of their subjects failed to produce a deflection point.

Conconi et al. (1982) designed a lactate test in order to validate their field test. In this test the subjects ran for 1200 metres at three intensities (velocities in this case) below and three intensities above the deflection velocity predicted in the field test.

Lactate measurements were taken 5 minutes after each 1200 metre run. The results were plotted and a line of best fit was drawn through the three points below the deflection velocity. A similar line was drawn through the three points above the deflection velocity. The intensity (velocity) coinciding with the intersection of these two lines represented the AnT, according to Conconi et al. (1982). They claimed that the field test was valid if the deflection intensity (velocity) predicted by it correlated highly with the intensity (velocity) of the lactate test.

Questions have arisen regarding the methods of lactate analysis used by Conconi et al. (1982). Tokmakidis et al. (1988) have problems with Conconi et al's.(1982) selection of three speeds below and three speeds above the deflection intensity (velocity in this case) as unbiased lactate testing points. They explain that since the deflection velocity has been used to determine which sets of three points the lines of best fit will be drawn through, the resulting intersection of these lines will always fall close to the deflection point. They suggest that if the 'traditional protocol' was followed and a curve was drawn through the points then the high correlations shown by Conconi et al. (1982) would not be reproduced.

In addition, they point out the problem of Conconi et al. taking lactate samples up to 5 minutes post exercise when at least three of the speeds were below the AnT. They mention that the lactate values could have started to decrease by the time they were taken. This could possibly lead to an over estimation of the AnT by lactate analysis.

Ribeiro et al. (1985) performed a study using two sample groups. Subjects of Group 1 performed only one Conconi test, whereas those of Group 2 performed two tests in order to establish a measure of reliability. All of the subjects in Group 1 produced a deflection point whereas only 50 % of the 16 subjects in Group 2 produced a deflection point in both tests. Ribeiro et al. (1985) report that "four subjects presented a deflection point in only one of the tests, and four subjects did not show a deflection point in either test" (p. 222). They concluded that the reliability of the Conconi test was poor.

Van Handel et al. (1988) reported an inability to detect heart rate deflections during incremental exercise testing. Their data show a linear relationship between workload and heart rate up to maximal levels of exercise. They suggest that if heart rate deflections do occur at all then they seem to approximate $\dot{V}O_2max$ and not the AnT.

5. Summary

In summary, the Conconi test has received support as a valid and reliable predictor of the intensity associated with the AnT by some researchers. In spite of this support, it has also been dismissed as an invalid and unreliable test by others. Ribeiro et al. (1985), after a critical review of the Conconi test, recommends further investigation of the test. The preceding literature review demonstrates the need for more research concerning the validity of the Conconi test. Conconi et al. (1982) claimed that their noninvasive test predicts an exercise intensity which can be maintained for prolonged periods without an accumulation of lactate in the blood (the AnT). A study which measures lactate concentration periodically during prolonged exercise at the Conconi predicted intensity could provide information which either support or refute the claims of Conconi et al. (1982). To date no research has been conducted which directly studies this aspect.

CHAPTER THREE

Method

1. Introduction

The data for the present study were collected in three stages. Each stage took place on a separate day. The subjects completed each stage within one hour and there was at least one day's rest between stages. At the first stage the subjects were required to complete a Conconi test on a cycle ergometer. During the second stage the subjects completed a $\dot{V}O_2max$ test on a cycle ergometer. The third stage involved the subjects who successfully completed the first stage. These subjects were required to cycle for 30 minutes or until exhaustion at a pre-determined exercise intensity.

The method chapter includes three major sections. The first contains information relating to the selection and description of the subjects used in the study. The second section describes the apparatus used to collect the data. Validity and reliability information relating to the apparatus used is discussed there. The third section entitled 'Measurement Techniques' provides information related to how each of the three tests were carried out. Each of the three tests is a variation of those used extensively throughout the sport science literature. Detailed descriptions of the variations used in the present study are included in Appendices B, C and D to which the reader is referred.

2. Subjects

The subjects for this study were selected from the sport science students at Edith Cowan University in Perth, Western Australia. The student group selected for this study contained 144 students. The subjects were sport science students who cycled at least three times a week at a recreational or competitive level. Twenty subjects, including ten females and ten males, volunteered to take part in the study. One female subject failed to attend any of the testing sessions so a further male student was recruited to maintain a sample size of 20. There were no set criteria regarding age during selection. The three subjects over the age of 35 years were required to obtain medical clearance before participation.

A summary of the descriptive statistics of the sample is presented in Table 1. The sample (N=20) was separated into females (n=9) and males (n=11) during analysis to allow for the gender differences apparent in body mass and $\dot{V}O_2max$. Mean ages were 24.67 years (SD= 6.65 years) and 27.91 years (SD= 7.96 years) for females and males respectively. Mean body mass was 59.2 kilograms (SD= 7.8 kg) for females and 73.6 kilograms (SD= 9.23 kg) for males.

$\dot{V}O_2max$ values appear in millilitres per kilogram per minute (ml/kg/min). These were derived prior to calculating mean values by dividing each subject's $\dot{V}O_2max$ value, in litres per minute (l/min), by their body mass in kilograms (kg). Mean $\dot{V}O_2max$ values were 53.98 ml/kg/min (SD= 5.74) and 64.13 ml/kg/min (SD= 5.87) for females and males respectively. The statistics presented above reveal a sample which was not homogeneous in respect to any of the three characteristics recorded (i.e. age, body mass and $\dot{V}O_2max$). For the data of individual subjects refer to Appendix E.

Permission to conduct the study was obtained from the "Higher Degrees Committee" and the "Committee For The Conduct Of Ethical Research" of Edith Cowan University. Prior to commencement of the study all of the subjects received a written handout explaining the proposed research. The handout included the relevant information which was required by the university's ethics committee. All of the subjects knew that they were at liberty to withdraw from the study at any stage without penalty. The handout contained an indemnity form which was signed by all of the subjects prior to data collection. A copy of the written handout with included indemnity form is included in Appendix A. The confidentiality was maintained by assigning each subject a number which was used throughout the study and in reporting the results.

Table 1

Descriptive Characteristics of Nine Female and Eleven Male Sport Science Students

	Females			Males		
	mean	SD	range	mean	SD	range
Age (years)	24.67	6.65	19 - 38	27.91	7.96	19 - 44
Body mass (kg)	59.20	7.8	51 - 75	73.68	9.23	56 - 92
$\dot{V}O_2max$ (ml/kg/min)	53.98	5.74	45.88 - 63.6	64.13	5.87	58.8 - 77.38

3. Apparatus

Collection of the research data took place in three stages. The apparatus that was used in collecting the data were as follows:

3.1 Stages 1 and 2

The cycle ergometer used for this study was the Monark model 829 E. The braking of the flywheel was controlled through instructions programmed into a compact hand held computer which was attached to the ergometer. The desired resistance settings for each subject's protocol were pre-programmed into the micro-computer's memory prior to testing. The Monark 829 E was fully internally calibrated prior to commencement of the study and tested each day through the 'daily validation check' in the instruction manual. Daily validation also contributed a measure of reliability. For additional information regarding the Monark 829 E cycle ergometer refer to Appendix F.

A Morgan metabolic cart with attached electrocardiograph, computer system and printer was used to collect heart rate (HR), minute ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$) and the respiratory exchange ratio (RER). Validity and reliability of the Morgan metabolic cart was checked by the process of running calibration gases through the analysers prior to testing each subject. The gas concentrations did not vary outside the allowable error ranges during the course of the study. A Chemtronics heart rate simulator was used to test the validity and reliability of the Morgan electrocardiograph. During the course of the study the electrocardiograph produced valid and reliable data.

A Polar Sports Tester - PE 3000 model was used during the study as a back-up system in the event of the Morgan based ECG failing to receive and record some of the heart rate data. The incoming heart rate data was stored every five seconds in the PE 3000's internal memory. At the completion of each test the stored heart rate data was down-loaded onto a IBM personal computer through the use of a RS-232 interface. In addition, the down-loaded data was saved onto a 3.5 inch floppy disk.

An electric fan was used to provide a constant flow of air onto the subjects during the tests and a Seca mass measurement instrument was used to measure the subjects' body masses.

3.2 Stage 3

At Stage 3 of the study the Monark 829 E ergometer and the electric fan were also used. In addition, at the third stage of the study lactate sampling equipment which included an Analox GM-7 analyser, a Microman pipette, Autolex lancets, herapinised capillary tubes and tube holding cards, surgical gloves (one pair per subject), Finalgon ointment, tissues, a thermal water container, a towel and a hot/cold injury pack were also used.

"The GM-7 used in the study was a multi-purpose single channel analyser used for the measurement of various oxidase substrates" (Operation and Maintainence manual, n.d., p. 1). The oxidase substrate measured in the present study was arterialized blood lactate. The GM-7 produced rapid results due to the use of a microlitre sample of blood lactate. A 7 microlitre sample size was used to measure lactate values up to 10 mmol/L. Values greater than 10 mmol/L were measured through the use of a 3.5 microlitre sample size. Three 7 microlitre samples were analysed from each capillary tube to ensure analyser reliability. If two or all lactate samples were within 0.2 mM of each other the average was determined and recorded. If one sample fell outside 0.2 mM of the other two it was discarded and the average of the remaining two was recorded. To ensure validity of the GM-7 analyser a known 8 mM sample was injected after every ten cycles. If the machine readout was greater or less than 0.2 mM from the 8 mM standard the machine was recalibrated and all samples back to the preceding known 8 mM sample were re-analysed.

4. Measurement Techniques

Collection of the data took place in three stages over a three-week period during the month of September. The duration of each stage was 45 minutes maximum per subject and, each of the three stages was separated by a rest period of at least one day. All subjects were requested:

a) not to partake in any moderate or intense exercise the day prior to each stage, and b) to consume their 'normal' meals the day prior to each stage.

Barometric pressure, temperature and relative humidity were recorded prior to testing the initial subject and updated prior to testing each subsequent subject. This practice was followed in all stages of the study.

4.1 Stage 1 - The Conconi Test.

Each subject performed a Conconi test on a Monark 829 E cycle ergometer. One subject was tested at a time and each subject had previously been issued with a schedule of times and dates of each test. The Conconi test involved the measurement of exercise intensity (workload) and heart rate during progressively increasing exercise. Upon test completion the data obtained was graphically represented, with workload plotted along the 'X' axis and heart rate along the 'Y' axis. The resulting graph was subjectively inspected for a deflection from linearity between the two measured variables. In the cases where a deflection was observed a line of best fit was drawn between the sets of points below it. The same process was followed for the sets of points occurring above the deflection. The resulting workload and/or heart rate corresponding to the deflection point (i.e. the intersection of the two drawn lines) was considered the exercise intensity coincident with the AnT, according to Conconi et al. (1988). In the cases were a deflection was not observed a line of best fit was drawn between the sets of data points to illustrate their linear pattern.

Measurement of oxygen uptake ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$) and the respiratory exchange ratio (RER) were also taken during the test. To date, traditional Conconi tests have not employed simultaneous measurement of heart rate and gas variables. This variation was added to the present study to allow the above gas variables to be measured at the Conconi-Predicted intensity. For a detailed description of the specific procedure used for the laboratory Conconi test refer to Appendix B.

4.2 Stage 2 - The Maximum Oxygen Uptake Test

Each subject in the sample performed a $\dot{V}O_2$max test on a Monark 829 E cycle ergometer. The $\dot{V}O_2$max test directly measured the subject's oxygen consumption during cycling exercise of increasing intensity. The largest oxygen consumption value measured during the latter stage of the test represented the subject's maximal capacity to consume oxygen.

The test used in the present study was a variation of the test suggested by Draper and Telford (1989). Their test was designed for elite cyclists who were being tested at the Australian Institute of Sport. The initial and incremental workloads used in the present $\dot{V}O_2$max test were reduced for both the female and male subjects. This was necessary in order for the subjects to complete the test in the desired range of 10 to 14 minutes. For a detailed description of the specific procedure used in the study refer to Appendix C.

4.3 Stage 3 - The Prolonged Cycle at the Conconi-Predicted Intensity

Each subject performed a cycle for 30 minutes or until exhaustion, at the Conconi-Predicted intensity, on a Monark 829 E cycle ergometer. Gas analysis was undertaken and arterialized blood was sampled at 5-minute intervals during the cycle and immediately upon cessation of the test. In addition, a lactate sample was also collected at 5 minutes after exercise from those subjects who failed to cycle in excess of 10 minutes. From these samples, lactate concentrations were assessed for the presence or absence of a lactate steady state. For a detailed description of the specific procedure used in the study refer to Appendix D.

CHAPTER FOUR

Presentation of Results

1. Introduction

The results of the study have been separated into two sections. The first section presents the results of the first stage of the study (the Conconi tests). Significant differences that appeared between the subjects' performances in the Conconi test are reported in tabular form. The second section presents the results of the prolonged cycle at the Conconi-Predicted AnT (Stage 3 of the study).

2. Conconi Tests

During the Conconi test, a deflection point (heart rate and/or work intensity) was determined by plotting each individual subject's heart rate against his/her work intensity during cycle ergometer exercise of an increasing intensity. Three distinct groups emerged during analysis of the Conconi tests.

The first group included those subjects who did not produce a deflection point during the Conconi test. Upon graphing individual results seven of the 20 subjects (35 %) produced a linear relationship (i.e. no noticeable deflection) between heart rate and work intensity. The seven subjects who did not produce a deflection point in the Conconi test were unable to complete Stage 3 of the study (the prolonged cycle at the Conconi-Predicted AnT). This was due to Stage 3 requiring an exercise intensity which can only be obtained after the subject deflects in the Conconi test.

The remaining 13 subjects in the sample (65 %) all produced deflection points during the Conconi test. Two subgroups, Group A (n=7)and Group B (n=6) emerged from the deflecting group during comparison of a variable referred to in Table 2 as "Deflection as a percentage (%) of $\dot{V}O_2max$".

Table 2

Conconi Deflection Points of Two Significantly Different Groups as a Percentage of $\dot{V}O_2max$.

	Group A	Group B
Subject Number	Deflection as a % of $\dot{V}O_2max$	Deflection as a % of $\dot{V}O_2max$
1	76.5	
2		86.9
4		94.5
5		88.2
6	68.6	
7		94.5
9		89
10		95
13	72	
14	67.7	
17	72.6	
18	74	
20	72.9	
n=	7	6
mean	72.04	91.35
SD	3.04	3.70
t-test (t=)	10.17	
df	9	
$p < 0.001$	Sig	

The preceding value was calculated by dividing each subject's litres per minute (l/min) result obtained in the $\dot{V}O_2max$ test by the l/min result obtained in the Conconi test. The individual results were then averaged to produce the mean score used in the comparison.

All of the subjects in group A produced deflection points at less than 85 % of their $\dot{V}O_2max$. The subjects of group B all deflected at greater than 85 % of their $\dot{V}O_2max$. Mean deflections as a percentage of $\dot{V}O_2max$ were 72.04 (SD= 3.04)and 91.35 (SD= 3.70) for the less than 85 % and greater than 85 % groups respectively. A t-test was performed on the $\dot{V}O_2max$ values of the two subgroups. The results displayed in Table 2 revealed a significant difference between the groups at a probability level of 0.001, t(9)=10.17. Appendix E contains the deflection points of individual subjects as heart rates, work intensities (watts) and percentages of the $\dot{V}O_2max$.

3. Prolonged Cycles at the Conconi-Predicted AnT

Stage 3 of the study was completed by the 13 subjects who produced deflection points in the Conconi test (Stage 1). There were two subgroups, Group C (n=5) and Group D (n=8), which were identified from the 13 subjects. Group C, shown in Table 3, consists of the five subjects who completed the 30-minute prolonged cycle at the Conconi-Predicted AnT. The remaining eight subjects, included in Group D, reached voluntary exhaustion prior to completing the 30-minutes of cycling (see Figure 2).

One of the five subjects in Group C failed to provide the required blood sample at the 25 and 30 minute points in the prolonged cycle. Due to the unavailability of the final two lactate values the presence of a lactate steady state could not be determined. Table 3 shows that three of the remaining four subjects in group C did not increase their individual lactate values by more than one mM during the final 20 minutes of the prolonged cycle. Heck et al. (1985) state that an increase in lactate of less than 1 mM over the last 20 minutes of a 30-minute lactate test is synonymous with a 'maximal lactate steady state'. In line with their conditions three of the subjects in Group C produced lactate responses coincident with a maximal lactate steady state. The fourth subject of group C did not begin to produce SSL responses until the fifteenth minute of the prolonged cycle. During the final 15 minutes the lactate value did not increase by more than one mM.

Table 3 shows the <u>mean</u> lactate values of Group C for the 5-minute intervals during the prolonged cycle at the Conconi-Predicted AnT. The mean lactate values did not increase in excess of 1 mM during the final 20 minutes of the prolonged cycle. This demonstrates that there was no clinically significant rise in lactate levels. In reference to the work of Heck et al. (1985) the mean lactate response was coincident with a maximal lactate steady state. A repeated measures Analysis of Variance (ANOVA) also demonstrated that there was no statistically significant rise in lactate levels $F(5, 15)=0.95$, $p>0.05$. The absence of a significant increase between the values of the tenth minute and any of the subsequent 5 minute values indicates that a lactate steady state was achieved by the four subjects of group C which were analysed (see Table 3). Further, Table 2 shows that the five subjects of group C were also a subset of group A as each subject deflected at less than 85 % of their $\dot{V}O_2max$.

Figure 2 shows the times and associated lactate values of the eight subjects who reached voluntary exhaustion during the prolonged cycle at the Conconi-Predicted AnT. Seventy five percent of the eight subjects ($\underline{n}=6$) who reached voluntary exhaustion deflected at greater than 85 % of $\dot{V}O_2max$ in the Conconi test. Time to

voluntary exhaustion of the eight subjects ranged from 2 minutes, 56 seconds to 23 minutes, with a mean time of 10.54 minutes (SD= 8.14 mins).

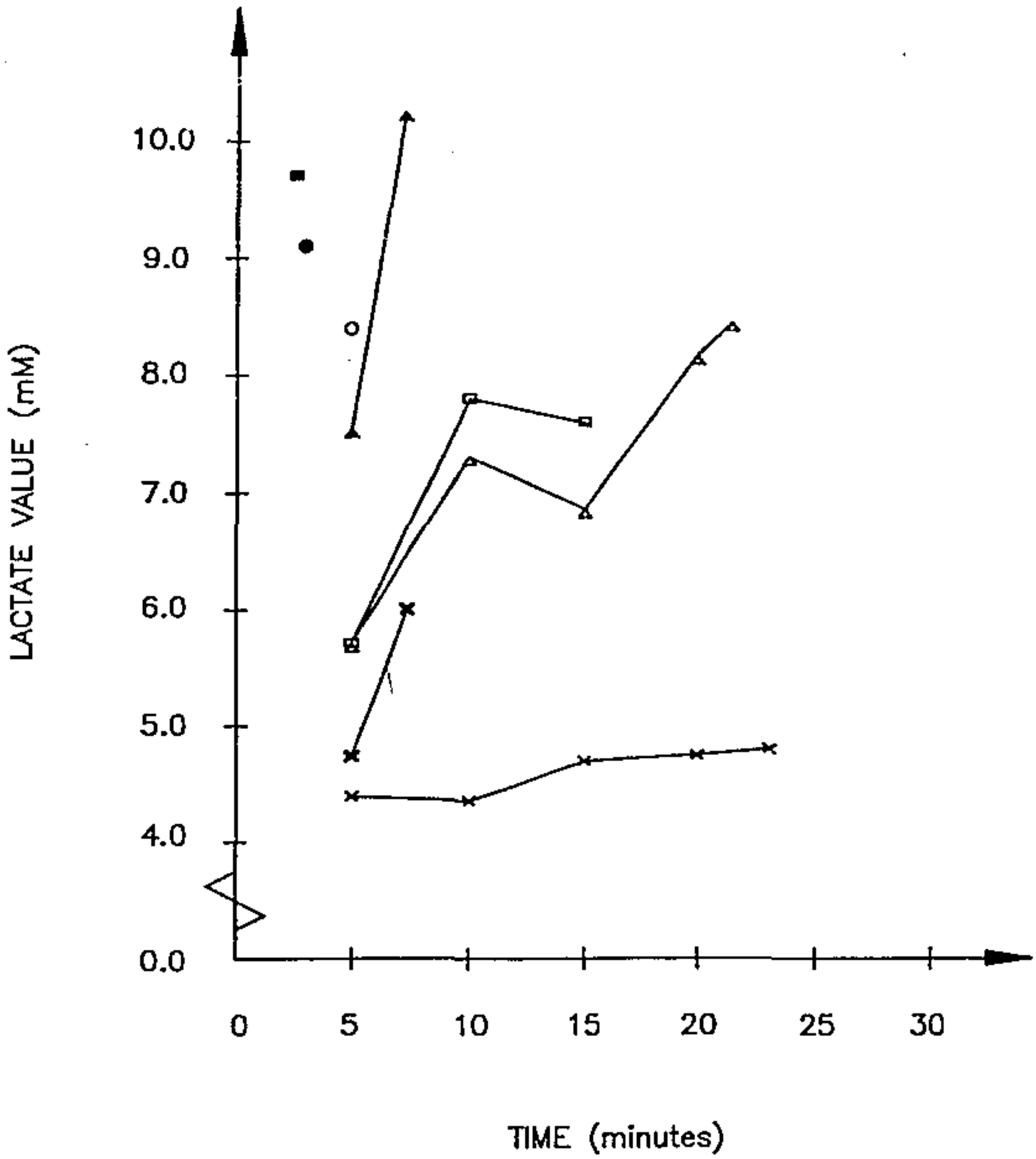
Table 3

Individual 5-Minute Lactate Values and Associated Repeated Measures ANOVA of the Subjects Who Cycled For 30 Minutes at the Conconi-Predicted AnT.

Subject Number	Group	5 minute (mM)	10 minute (mM)	15 minute (mM)	20 minute (mM)	25 minute (mM)	30 minute (mM)
1	C	4.3	5.1	5.85	5.3	4.85	5.4
6**	C	3.9	4.9	6.6	not obtained	not obtained	not obtained
17	C	5.1	4.3	7.1	5.8	7.7	5.3
18	C	3.35	4.8	4.25	3.75	4.3	3
20	C	4.1	3.55	3.5	3.1	3.35	3.95
n=		4	4	4	4	4	4
Mean		4.2125	4.4375	5.175	4.4875	5.05	4.4125
SD		0.7192	0.6774	1.6147	1.2717	1.8721	1.1506
Repeated Measures ANOVA (F=)		0.95					
df		5, 15					
Sig ($p < 0.1$)		ns					

** Data from subject number six was not used in calculation of the ANOVA F ratio due to the absence of lactate values for minutes 20 through 30

FIGURE 2: Individual lactate responses of the subjects (Group D) which failed to complete 30 minutes of cycling at the Conconi–predicted AnT.



LEGEND :

× Subject 2
✖ Subject 4
▵ Subject 5
▲ Subject 7
▫ Subject 9
■ Subject 10
○ Subject 13
● Subject 14

CHAPTER FIVE

Discussion

1. Introduction

The purposes of the study were to investigate the effect of prolonged cycling at the Conconi-Predicted AnT and to quantify the percentage of $\dot{V}O_2max$ the Conconi test predicted. It was envisaged that the results of the study would be used either to add support to or to question the use of the Conconi test as a predictor of the AnT. Three tests were used to collect the data used in the present study. These included the Conconi test (Stage 1), the $\dot{V}O_2max$ test (Stage 2) and the prolonged cycle at the Conconi-Predicted AnT (Stage 3). The discussion is divided into three sections. These sections discuss the present findings in light of the work of other researchers wherever possible. The first section addresses the subjects of the study, and the second and third sections discuss the results of the Conconi tests and the prolonged cycle at the Conconi-Predicted AnT, respectively.

2. The Sample

As can be seen from Table 1, the sample used for the study were not homogeneous in respect to age, body mass or $\dot{V}O_2max$ even when separated into categories according to sex. This is not unique to the present study as other studies have also used subjects whose level of conditioning and physical characteristics have differed (Ballarin, Borsetto, Cellini, Patracchini, Vitiello, Ziglio and Conconi, 1989; Ribeiro et al., 1985).

Five of the male subjects were currently or had previously cycled on a competitive level. None of the female subjects reported any history of competitive cycling prior to the study. Three of the male and four of the female subjects reported running on a regular basis. When compared to normative data, all of the subjects that participated in the study achieved results well above average in regard to maximum oxygen uptake (Astrand, 1960).

3. The Conconi Tests

The Conconi tests produced unexpected results in the present study. Based on pilot research conducted prior to the main study in which all of the subjects (n= 5) produced deflection points, it was hypothesized that all 20 of the subjects in the main study would deflect. This third hypothesis of the study was rejected when seven of the 20 subjects failed to produce a deflection point. Other researchers have similarly reported cases where up to 100 % of their subjects failed to deflect (Ribeiro et al., 1985; Van Handel et al., 1988). In cases where a subject fails to deflect it is impossible to predict the AnT. The fact that 35 % of subjects failed to produce deflection points adds support to the case suggesting that the Conconi test is not a valid predictor of the AnT.

In the past it has been suggested that the reason subjects may fail to deflect could be due to their being unfamiliar with the mode of exercise used in the tests. In the present study one of the criteria for acceptance was that subjects cycled recreationally or competitively at least three days per week.

From the work of other researchers it has been suggested that the AnT occurs between 50 and 90 % of an athlete's $\dot{V}O_2max$ (Longhurst and Blundell, 1986; Lopategui et al., 1986; Orok et al., 1989). An AnT of 90 % of $\dot{V}O_2max$ would be reserved for those who possessed a high degree of cardiorespiratory fitness. In light of the work of Tokmakidis and Leger (1988) and Van Handel et al. (1986) which suggested that the Conconi test over-predicts the AnT, it was hypothesized that all of the subjects would produce a deflection point which corresponded to an exercise intensity greater than 85 % of their $\dot{V}O_2max$.

The collection of oxygen uptake values during the Conconi test was unique to this study. The results, therefore, could not be directly compared to any similar study. Through the inclusion of the second stage of the study, it was possible to obtain the subjects' $\dot{V}O_2max$ scores. By dividing the oxygen uptake value corresponding to the deflection point by the $\dot{V}O_2max$ score, the percentage of $\dot{V}O_2max$ coinciding with the predicted AnT was located. As both the Conconi and $\dot{V}O_2max$ tests were one minute incremental tests it was possible to perform the above calculations. The data obtained was then able to be compared to the work of the above mentioned researchers.

The second hypothesis of the study stated that each subject's oxygen consumption value measured at the deflection point during the Conconi test would correspond to an intensity greater than 85 % of their $\dot{V}O_2max$. The results of the study failed to support this hypothesis.

In the first instance the above hypothesis could only be tested on 13 of the 20 subjects. The remaining seven subjects failed to produce deflection points during the Conconi test. In cases where a deflection point is not produced, a corresponding oxygen uptake value cannot be located. Therefore, in these seven subjects it was not possible to determine whether the subjects' deflection points corresponded to intensities less than or greater than 85 % of $\dot{V}O_2max$.

Secondly, upon analysis, two significantly different groups emerged when the variable 'percentage of $\dot{V}O_2max$' was considered. Table 2 shows one of the groups, containing seven of the remaining 13 subjects, produced deflection points which corresponded to less than 85 % of their $\dot{V}O_2max$. In relation to the total sample only 30 % of the subjects deflected at greater than 85 % of their $\dot{V}O_2max$. Even if the comparisons were restricted to those subjects who produced a deflection point there would still be only 46 % of the subjects who deflected at greater than 85 % of their $\dot{V}O_2max$.

4. Prolonged Cycles at the Conconi-Predicted AnT

Due to 35 % of the subjects failing to produce deflection points in the Conconi tests only 65 % of the subjects were able to perform a prolonged cycle at the Conconi-Predicted AnT. Two groups emerged from the 13 subjects who performed the prolonged cycle. One of the groups contained five subjects who all completed the 30-minute cycle. The second group contained the remaining eight subjects who failed to complete 30-minutes of cycling at the Conconi-Predicted AnT.

Three of the five subjects who completed the 30 minutes of cycling produced SSL responses when the individual lactate responses were analysed clinically. Heck et al. (1985) considered an increase in lactate of less than one mM over the last 20 minutes of exercise representative of a MLaSS. A fourth subject produced lactate values which did not increase by more than one mM over the last 15 minutes of exercise. Heck et al. (1985) suggested that the last 20 minutes of exercise be used as some of their subjects had lactate values which were still rising after the first 5 minutes. In the case of the fourth subject the lactate did not plateau until the fifteenth minute of the cycle. Once the plateau was achieved the remaining lactate response was similar to those associated with a steady state.

When the mean lactate responses of four of the five subjects who cycled for 30-minutes were analysed clinically, the mean lactate values did not increase by more than 1 mM over the last 20 minutes of exercise. According to the definition of Heck et al. (1985) the four subjects produced MLaSS. In order to ensure that the lactate steady state was maximal in nature Dal Monte (1988) suggests that subsequent fixed intensity cycles would need to be performed at higher workloads. If the lactate values continuously increased over the subsequent cycles then the initial cycle did produce a MLaSS. Due to the extra time that would have been required to perform these tests, the Dal Monte method was not employed in the present study. Although the four subjects produced lactate steady state responses there was a possibility that these were not coincident with a MLaSS.

Further research could involve exercising those subjects who produced SSL responses for prolonged periods at one or two intensities slightly above those of the Conconi deflection. The presence or absence of lactate steady state responses during the additional prolonged exercise bouts would help to establish whether the Conconi predicted intensity produced a MLaSS response.

A repeated measures analysis of variance was also applied to the data of the four subjects who completed the prolonged 30-minute cycle. The results of the statistical analysis were in agreeance with those of the clinical analysis. Table 3 shows that statistically there was no significant difference between the lactate values of the last 20 minutes of exercise.

The fifth subject who completed the 30 minute cycle at the Conconi-Predicted AnT failed to produce the required blood samples from the twentieth minute until the end of the test. Due to the absence of lactate values for the three 5-minute periods, a lactate steady state response could not be determined. Difficulty in obtaining blood could possibly be due to vasoconstriction in the arms and hands of the subject. The legs would be demanding a large supply of blood to perform the required cycling exercise thereby causing a lack of blood flow to the fingers. The earlobe was deemed an inappropriate site for blood collection in the case of the present study due to the oxygen consumption head gear worn by the subjects.

The Conconi test was designed to predict an exercise intensity which corresponds to the AnT. It is known that an exercise intensity corresponding to the IAT will produce a SSL response. Four of the five subjects who cycled for 30 minutes produced SSL responses. In addition all five of the subjects who cycled for 30-minutes produced deflections which occurred at less than 85 % of their $\dot{V}O_2max$. In fact, these five subjects all deflected between 60 and 80 % of their $\dot{V}O_2max$ scores. The literature suggests that the AnT generally occurs between 50 and 90 % of $\dot{V}O_2max$ for most athletes (Longhurst and Blundell, 1986; Lopategui et al., 1986; Orok et al., 1989). In light of the information presented above it seems that the Conconi test may have provided correct predictions for 25 % of the subjects in the study, however, some of these subjects could possibly have worked at a higher exercise intensity and maintained a MLaSS which further challenges the test's validity.

Although the Conconi test may have predicted approximately the AnT for 25 % of the subjects, it produced results which were invalid for the remaining 75 %. In these cases it was impossible to determine an intensity which corresponded to the AnT. The remaining eight subjects (40 %) who attempted the prolonged cycle all failed to complete the 30 minutes of exercise. Figure 2 shows that the duration of cycling ranged from just under three minutes to 23 minutes. From Figure 2 it can also be seen that in six of the eight subjects the terminal lactate value was at least eight mM. Lactate values of around ten mM have been associated with intensities approximating those of $\dot{V}O_2max$ in athletes. Stegmann and Kindermann (1982) reported individual anaerobic thresholds (IAT) ranging from 1.8 to a maximum of 6.1 mM in physical education students. They also reported that "in physical education students the mean lactate concentration at the IAT has been found to be 4.6 mM". The above statements together with the suggestion by Heck et al. (1985) that the AnT generally occurs close to a lactate value of 4 mM, it is plausible to expect that the AnT of the above six subjects were overestimated. Stegmann and

Kindermann (1982) stated that "all of their athletes could have tolerated exercise at the IAT for more than 50 minutes". The mean $\dot{V}O_2max$ values of the female subjects of the present study were similar to those of Stegmann and Kindermann's (53.98 ± 5.74 versus 53.4 ± 3.3), while the male subjects exceeded those of Stegmann and Kindermann's (64.13 ± 5.87 versus 56.0 ± 5.7) The times to exhaustion of less than 30 minutes for the six subjects, together with the above statement by Stegmann and Kindermann regarding exercise tolerance at the IAT, provides further support to the claim that the Conconi test is an invalid predictor of the AnT.

Six of the eight subjects who failed to complete the prolonged cycle deflected at greater than 85 % of their $\dot{V}O_2max$. From the extremely short cycle time and elevated lactate values it seems that the remaining two subjects were cycling above their AnT's. If this was correct then it can be seen from Table 2 that these two subjects would have had AnT's which occurred at less than 85 % of their $\dot{V}O_2max$.

The first hypothesis of the study stated that the Conconi test would overestimate the AnT, causing blood lactate concentrations to rise continuously in all subjects over the duration of a prolonged cycle at the Conconi-Predicted AnT.

This hypothesis was rejected when 25 % of the subjects produced SSL responses during the prolonged cycle. Sixty one percent of the subjects who completed the Conconi test produced lactate responses in the prolonged cycle which supported the above hypothesis.

In Summary, the three hypotheses stated in the introduction of the study were rejected. The suggestion though, by numerous researchers, that the Conconi test is an invalid predictor of the AnT has been supported by the study. The findings of this research suggest that the coach, sport scientist and/or athlete should not use the

Conconi test as a tool for predicting the AnT. It should be noted that the results of this research are not suggesting that the intensity corresponding with the Conconi deflection point has no place in an athlete's training program. What it is suggesting, however, is that when deflection points can be determined from Conconi tests, the majority will not be coincident with the AnT. A variety of training intensities, other than those associated with the AnT, are valuable during certain cycles of a training plan, and Conconi derived intensities may well fall within those which are acceptable.

5. Conclusions

Based on the results of this study the following conclusions were reached:

1. The Conconi test will not produce deflection points in all subjects.

2. The exercise intensity predicted by the Conconi test will not produce lactate steady state responses in all subjects.

3. The Conconi-Predicted AnT does not correspond to an exercise intensity above 85 % $\dot{V}O_2max$ in all subjects.

6. Recommendations for Further Studies

The findings and limitations of the present study suggest a number of directions for further research.

1. One or two more cycles at fixed intensities above those which produced SSL responses could be added to determine whether a MLaSS was achieved.

2. A more effective method of producing a hyperemic finger is needed to ensure that blood is obtained at each sampling interval. A venous catheter may be inserted in preference to the arterialised blood taken from a hyperemic finger.

3. A more homogeneous group of subjects could be used to check for similar results.

4. It would be interesting to repeat the study using an electrically braked cycle ergometer, and compare the results to those obtained from the mechanically braked version used in the present study.

5. A similar study to the present one, conducted in a field situation using racing cycles, a cycling track (i.e. a velodrome), and trained cyclists would be interesting for comparison with the present study. In addition, the testing ergometers and cycling style would be more specific to those used in the sport of cycling, and hence the results may be more meaningful to cycling coaches.

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APPENDIX A

INFORMED CONSENT FORM COMPLETED BY SUBJECTS PRIOR TO PARTICIPATION IN THE TESTING.

EDITH COWAN UNIVERSITY INFORMED CONSENT FOR VOLUNTARY PARTICIPATION IN:

A RESEARCH STUDY EXAMINING THE EFFECT OF PROLONGED CYCLING AT THE CONCONI-PREDICTED ANAEROBIC THRESHOLD ON BLOOD LACTATE CONCENTRATIONS.

INTRODUCTION

The anaerobic threshold (AnT) is the highest exercise intensity possible without an increase in blood lactate levels. It is used to prescribe optimal training intensities for aerobic endurance type events. Researchers, coaches and athletes have adopted tests of the AnT to supplement the decision making processes involved in designing athlete's periodised training programmes.

The problem associated with traditional measures of the AnT is that they involve expensive and sometimes invasive laboratory tests. However in 1982 Conconi et al developed a non - invasive field test to predict an intensity which corresponded to the AnT. This test which is cheap and easy to administer has a reported 0.99 correlation with the AnT as measured by traditional tests, and has been adapted for use in a laboratory setting , thus allowing cycle ergometers and treadmills to be used. Furthermore many athletes who have designed their training programmes on the basis of Conconi-predicted intensities have enjoyed enormous success at an international level.

Certain researchers have questioned the validity of the Conconi test as an accurate predictor of the AnT. Problems associated with the percentage of maximum oxygen uptake this test predicted, internal validation, and an inability to locate heart rate deflection points, were some of the aspects raised by researchers.

Purposes of the study

1. To investigate the effect of prolonged cycling at the Conconi-predicted AnT on blood lactate concentrations and
2. To quantify the percentage of maximum oxygen uptake the Conconi test predicts.

Procedures and sequence of the study

The study will be completed in three stages. Each stage will be completed in one day with a one day rest between stages.

1. Stage one requires the subjects to perform a Conconi Test on a cycle ergometer. During this test the subjects will:

   1.1 Cycle on a Monark 829 E cycle ergometer at increasing workloads to determine a predicted anaerobic threshold.
   Heart rate monitoring and gas collection will occur as in 1.2 above.

2. Stage Two requires the subjects to perform a maximum oxygen uptake test on a cycle ergometer. During this test the subjects will:

   2.1 Have their height, weight and age measured and recorded.

   2.2 Cycle on a Monark 829 E cycle ergometer at increasing workloads to determine Maximum Oxygen Uptake ($\dot{V}o2max$).
   During the cycle the subjects will have their heart rate monitored with an electrocardiograph (ECG) and oxygen consumption will be measured directly by a Morgan Gas Analyser.

3. Stage three requires the subjects to perform a prolonged cycle on a cycle ergometer.
   During this test the subjects will:

   3.1 Cycle on a Monark 829 E cycle ergometer for 30 minutes or until exhaustion at the workload predicted in the Conconi test (see 2 above)
   Blood lactate samples will be obtained at rest and at five minute intervals during the test. In the event of the subject failing to complete the 30 minute cycle a blood lactate sample will be obtained immediately upon test termination.

<u>Possible discomfort and hazards</u>

In order to collect the data required for this study it will be necessary for the subjects to:

1. Complete a maximum oxygen uptake test on a cycle ergometer. This test is maximal in nature and therefore exercises the subject to voluntary exhaustion.

2. Complete a Conconi test on a cycle ergometer. This test is maximal in nature and therefore exercises the subject to voluntary exhaustion.

3. Complete prolonged exercise on a cycle ergometer. This test has the potential to be maximal in nature and may therefore exercise a subject to voluntary exhaustion. The difficulty level of the prolonged cycle will be determined upon analysing the results of the preceding Conconi test.

4. Wear a PE3000 Sports Tester and / or ECG electrodes during each stage.

5. Wear gas collection apparatus during each stage. The apparatus will consist of

   5.1 A mouth piece
   5.2 A nose clip and
   5.3 Some head gear to hold the tubing connected to the mouth piece.

6. Have blood samples taken at rest and at 5 minute intervals during the prolonged cycle (stage three).

   6.1 The blood will be obtained via a small puncture in a pre warmed finger. The puncture will be achieved by use of a lancet. Finalgon ointment (a deep heat type cream) will be used to warm the finger prior to puncture. This allows more blood to flow to the fingertip for collection.

6.2 A small quantity of blood (approximately half a capillary tube) is all that is required at each five minute interval of the prolonged cycle.

The staff member supervising the study has undergone training (October 1989) in the use of the defibrillator which is located in the laboratory at which the testing will take place. The medical staff at the University will be notified of the dates that testing will take place in the event of any medical problems arising. In addition, the technician in charge of the laboratory is a qualified nurse.

Time involvement

The study will require the following time commitments from the subjects:

1. Briefing session	20 minutes	
2. Maximal oxygen uptake test (day one) maximum	45	minutes
3. Conconi test (day two) maximum	45	minutes
4. Prolonged cycle (day three) maximum	45	minutes

Benefits for the individual and society

The subject who participates in the study will benefit by having:

1. Their maximum oxygen uptake determined for free. This may cost up to $100 or more in a private commercial setting.

2. Their anaerobic threshold predicted via the Conconi test for free. This may cost a minimum of $30 dollars in a commercial setting.

Society will benefit through gaining more information regarding:

1. The validity of the Conconi test as a tool for predicting an exercise intensity which elicits a maximal lactate steady state during prolonged cycling.

2. The % of the maximal oxygen uptake the Conconi test predicts.

Anominity of the subjects involved in the study

In order to protect the identity of all individuals participating in the study each subject will be allocated a number which will be used instead of their name throughout the study. The only information including the subjects names will be the informed consent forms completed prior to the study. The numbers associated with the subjects during the study will not be included on the consent forms therefore no connection could be made between published results and any individual.

Withdrawal from the study

A subject is free to withdraw from the study at any time without incurring any form of **penalty.** Due to the subjects being university students it is appropriate to mention that failure to complete the study will in no way affect their academic standing within the department or institution.

Questions

Any questions concerning the project entitled

THE EFFECT OF PROLONGED CYCLING AT THE CONCON-PREDICTED ANAEROBIC THRESHOLD ON BLOOD LACTATE CONCENTRATIONS

can be directed:

Mr Michael Ponchard	Honours student supervisor on 3838269
Mr Michael Newton	Principal investigator on 2722176

Mr Ponchard is a staff member and Mr Newton is an honours student of the Department of Human Movement Studies at Edith Cowan University.

Consent

I.. have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, realising I may withdraw at any time.

I agree that the research data gathered for this study may be published provided my name is not used.

....
Participant or authorized representative Date

....
Investigator Date

APPENDIX B

PROCEDURE FOR STAGE ONE: THE CONCONI TEST

1. All measurement equipment was calibrated prior to the testing session.
2. The computer section of the Morgan metabolic cart was set up to measure minute ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RER) and heart rate (HR) every 15 seconds during the test.
3. The 'patient profile' section of the computer package was set up ready for entry of subject data.
4. The subject's height, weight and age were measured and recorded into the 'patient profile' section (see 3. above).
5. The handle bar and seat positioning were adjusted on the ergometer to suit the subject.
6. The subject was prepared for the test in the following manner:

   The standard three lead electrocardiograph (ECG) electrode placement sites (manubrium, left and right fifth intercostal space - mid clavicular)were cleaned with an alcohol swab and the ECG was fastened into place. A nose clip and three way breathing valve were positioned onto the subject's head and an electric fan was placed in front of the subject to provide a constant breeze.
7. The subject was re-briefed about the forthcoming cycle procedure including how to indicate their fatigue level through use of the Borg scale which was positioned on the wall in front of them and slightly above head level.
8. The subject warmed up for 10 minutes at a comfortable intensity (less than 100 watts).
9. At completion of warm up subject immediately began pedalling at 40 watts.
10. Exercise intensity was increased at 10 watts per minute for females and 20 watts for males.
11. Cycle workload was recorded during each minute of the test.
12. The test was terminated when the subject fulfilled one or both of the 'criteria to establish a valid test result', or produced ECG traces deemed subjectively to warrant test termination.

13. The heart rate and workload data gathered during the test was graphed and subjectively inspected for a deflection point.

CRITERIA TO ESTABLISH A VALID TEST RESULT

1. Subject's inability to maintain the set workload for 20 seconds or more.
2. Due to the availability of RER values (not available in traditional testing), a value in excess of 1.10 was used.

APPENDIX C

PROCEDURE USED FOR THE MAXIMUM OXYGEN UPTAKE TEST

1. All measurement equipment was calibrated prior to the testing session.
2. The computer section of the Morgan metabolic cart was set up to measure minute ventilation (VE), oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RER) and heart rate (HR) every 15 seconds during the test.
3. The 'patient profile' section of the computer package was set up ready for entry of subject data.
4. The subject's height, weight and age were measured and recorded into the 'patient profile' section (see 3. above).
5. The handle bar and seat positioning were adjusted on the ergometer to suit the subject.
6. The subject was prepared for the test in the following manner:

   The standard three lead electrocardiograph (ECG) electrode placement sites (manubrium, left and right fifth intercostal space - mid clavicular) were cleaned with an alcohol swab and the ECG was fastened into place. A nose clip and three way breathing valve were positioned onto the subject's head and an electric fan was placed in front of the subject to provide a constant breeze.
7. The subject was re-briefed about the forthcoming cycle procedure including how to indicate their fatigue level through use of the Borg scale which was positioned on the wall in front of them and slightly above head level.
8. A 4 minute warm up was undertaken at an exercise intensity of 40 watts (60 for males).
9. At completion of the warm up, exercise intensity was increased to 60 watts for females and 100 watts for males.
10. The exercise intensity was increased by 15 watts per minute for females and 25 watts per minute for males.

11. The cycle workload was recorded at the end of each minute.
12. The test was terminated when the subject fulfilled one or both of the 'criteria to establish a valid test result', or produced ECG traces deemed subjectively to warrant test termination.
13. Time to exhaustion fell between 10 and 14 minutes.
14. Upon reaching the end of the test the subject's $\dot{V}O_2max$ score was recorded.

The maximum oxygen uptake corresponded to the largest $\dot{V}O_2$ measured during the latter stage of the test. The resulting $\dot{V}O_2$ in litres per minute was converted into millilitres per minute. This was then divided by the subject's bodyweight to give a $\dot{V}O_2max$ value in millilitres per kilogram per minute (ml/kg/min).

CRITERIA USED TO ESTABLISH A VALID TEST RESULT

a) A plateau in $\dot{V}O_2$ (less than 2 ml/kg / min or 150 ml/min) or a slight drop with an increased workload.
b) A respiratory exchange ratio (RER) exceeding 1.10.

APPENDIX D

PROCEDURE FOR STAGE THREE: THE PROLONGED CYCLE AT THE CONCONI-PREDICTED AnT.

1. All measurement equipment was calibrated prior to the testing session.
2. The computer section of the Morgan metabolic cart was set up to measure minute ventilation (VE), oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RER) and heart rate (HR) every 15 seconds during the test.
3. The 'patient profile' section of the computer package was set up ready for entry of subject data.
4. The subject's height, weight and age were measured and recorded into the 'patient profile' section (see 3. above).
5. The handle bar and seat positioning were adjusted on the ergometer to suit the subject.
6. The subject was prepared for the test in the following manner:

   The standard three lead electrocardiograph (ECG) electrode placement sites (manubrium, left and right fifth intercostal space - mid clavicular) were cleaned with an alcohol swab and the ECG was fastened into place. A nose clip and three way breathing valve were positioned onto the subject's head and an electric fan was placed in front of the subject to provide a constant breeze. A surgical glove was placed onto the subject's hand. The subject was instructed to place their hand onto a heated hot/cold injury pack which was placed onto the ergometer handlebar. A towel was wrapped around the gloved hand and hot/cold pack to shield it from the electric fan's air flow.
7. The subject was re-briefed about the forthcoming cycle procedure including how to indicate their fatigue level through use of the Borg scale which was positioned on the wall in front of them and slightly above head level.
8. Subject warmed up for 10 minutes at a comfortable power output. close to but not exceeding the deflection power output.
9. Upon completion of warm up subject began pedalling at the Conconi-predicted power output (ie. deflection power output.).
10. Subject maintained this workload for 30 minutes or until exhaustion.

11. Half of a capillary tube of arterialized blood lactate was collected every five minutes throughout the cycle from a hyperemic finger tip. The subject's hand was temporarily removed from the towel and glove in order to the obtain blood. Upon collection of the blood the hand was immediately gloved and returned to the towel and hot/cold pack. A blood sample was taken immediately after testing when the subject reached exhaustion between the scheduled five minute collection times.
12. The test was terminated when the subject had either cycled for 30 minutes, was unable to maintain the set workload or produced any ECG traces which were subjectively deemed abnormal and warranting test termination.
13. Lactate concentrations of each of the collected blood samples were measured and recorded. The blood samples were rocked for at least three minutes prior to administration into the Analox GM-7 analyser.

APPENDIX E

INDIVIDUAL SUBJECT'S DATA FROM THE THREE TESTING SESSIONS

SUBJECT ONE

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	21
BODY MASS (KG)	55
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	2.52
$\dot{V}O_2$MAX (ML/KG/MIN)	45.88
$\dot{V}O_2$MAX (WATTS)	195
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	110
DEFLECTION (HEART RATE)	171
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	1.93
DEFLECTION AS A % OF $\dot{V}O_2$MAX	76.5
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	4.3
LACTATE - 10 MIN (mM)	5.1
LACTATE - 15 MIN (mM)	5.85
LACTATE - 20 MIN (mM)	5.3
LACTATE - 25 MIN (mM)	4.85
LACTATE - 30 MIN (mM)	5.4
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT TWO

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	25
BODY MASS (KG)	64
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.3
$\dot{V}O_2$MAX (ML/KG/MIN)	51.5
$\dot{V}O_2$MAX (WATTS)	250
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	220
DEFLECTION (HEART RATE)	173
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	2.87
DEFLECTION AS A % OF $\dot{V}O_2$MAX	86.9
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	4.4
LACTATE - 10 MIN (mM)	4.35
LACTATE - 15 MIN (mM)	4.7
LACTATE - 20 MIN (mM)	4.75
LACTATE - 23 MIN (mM)	4.8
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT THREE

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	19
BODY MASS (KG)	64
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.43
$\dot{V}O_2$MAX (ML/KG/MIN)	52.75
$\dot{V}O_2$MAX (WATTS)	240
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A SUBJECT DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT FOUR

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	21
BODY MASS (KG)	92
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	5.46
$\dot{V}O_2$MAX (ML/KG/MIN)	59.35
$\dot{V}O_2$MAX (WATTS)	400
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	340
DEFLECTION (HEART RATE)	184
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	5.16
DEFLECTION AS A % OF $\dot{V}O_2$MAX	94.5
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	4.75
LACTATE - 7.3 MIN (mM)	6
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT FIVE

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	30
BODY MASS (KG)	75
DATA FROM $\dot{V}O_2MAX$ TEST	
$\dot{V}O_2MAX$ (L/MIN)	4.94
$\dot{V}O_2MAX$ (ML/KG/MIN)	65.83
$\dot{V}O_2MAX$ (WATTS)	340
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	275
DEFLECTION (HEART RATE)	179
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	4.36
DEFLECTION AS A % OF $\dot{V}O_2MAX$	88.2
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	5.75
LACTATE - 10 MIN (mM)	7.35
LACTATE - 15 MIN (mM)	6.85
LACTATE - 20 MIN (mM)	8.15
LACTATE - 21.3 MIN (mM)	8.45
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT SIX

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	19
BODY MASS (KG)	59
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.033
$\dot{V}O_2$MAX (ML/KG/MIN)	51.4
$\dot{V}O_2$MAX (WATTS)	190
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	148
DEFLECTION (HEART RATE)	177
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	2.08
DEFLECTION AS A % OF $\dot{V}O_2$MAX	68.6
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	3.9
LACTATE - 10 MIN (mM)	4.9
LACTATE - 15 MIN (mM)	6.6
LACTATE - 20 MIN (mM)	UNABLE TO OBTAIN BLOOD
LACTATE - 25 MIN (mM)	UNABLE TO OBTAIN BLOOD
LACTATE - 30 MIN (mM)	UNABLE TO OBTAIN BLOOD
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT SEVEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	44
BODY MASS (KG)	79
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	5.13
$\dot{V}O_2$MAX (ML/KG/MIN)	66.7
$\dot{V}O_2$MAX (WATTS)	375
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	340
DEFLECTION (HEART RATE)	171
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	4.85
DEFLECTION AS A % OF $\dot{V}O_2$MAX	94.5
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	7.5
LACTATE - 7.2 MIN (mM)	10.2
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT EIGHT

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	29
BODY MASS (KG)	69.5
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.64
$\dot{V}O_2$MAX (ML/KG/MIN)	59.3
$\dot{V}O_2$MAX (WATTS)	325
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT NINE

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	19
BODY MASS (KG)	60.8
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.55
$\dot{V}O_2$MAX (ML/KG/MIN)	58.3
$\dot{V}O_2$MAX (WATTS)	270
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	175
DEFLECTION (HEART RATE)	178
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	3.16
DEFLECTION AS A % OF $\dot{V}O_2$MAX	89
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	5.7
LACTATE - 10 MIN (mM)	7.8
LACTATE - 15 MIN (mM)	7.6
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT TEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	19
BODY MASS (KG)	72.5
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.2
$\dot{V}O_2$MAX (ML/KG/MIN)	61
$\dot{V}O_2$MAX (WATTS)	320
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	250
DEFLECTION (HEART RATE)	188
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	3.99
DEFLECTION AS A % OF $\dot{V}O_2$MAX	95
DATA FROM PROLONGED CYCLE	
LACTATE - 2.56 MIN (mM)	9.7
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	7.6

SUBJECT ELEVEN

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	32
BODY MASS (KG)	52
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.09
$\dot{V}O_2$MAX (ML/KG/MIN)	58.34
$\dot{V}O_2$MAX (WATTS)	160
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT TWELVE

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	38
BODY MASS (KG)	52
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.31
$\dot{V}O_2$MAX (ML/KG/MIN)	63.6
$\dot{V}O_2$MAX (WATTS)	210
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT THIRTEEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	20
BODY MASS (KG)	68
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4
$\dot{V}O_2$MAX (ML/KG/MIN)	58.8
$\dot{V}O_2$MAX (WATTS)	400
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	205
DEFLECTION (HEART RATE)	178
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	2.87
DEFLECTION AS A % OF $\dot{V}O_2$MAX	72
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	8.4
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	6.85

SUBJECT FOURTEEN

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	22
BODY MASS (KG)	75
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	3.54
$\dot{V}O_2$MAX (ML/KG/MIN)	47.26
$\dot{V}O_2$MAX (WATTS)	225
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	170
DEFLECTION (HEART RATE)	186
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	2.4
DEFLECTION AS A % OF $\dot{V}O_2$MAX	67.7
DATA FROM PROLONGED CYCLE	
LACTATE - 3 MIN (mM)	9.1
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	8.9

SUBJECT FIFTEEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	25
BODY MASS (KG)	56
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.33
$\dot{V}O_2$MAX (ML/KG/MIN)	77.38
$\dot{V}O_2$MAX (WATTS)	350
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT SIXTEEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	28
BODY MASS (KG)	70
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.33
$\dot{V}O_2$MAX (ML/KG/MIN)	60.96
$\dot{V}O_2$MAX (WATTS)	350
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT SEVENTEEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	28
BODY MASS (KG)	68.5
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.54
$\dot{V}O_2$MAX (ML/KG/MIN)	65.84
$\dot{V}O_2$MAX (WATTS)	400
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	295
DEFLECTION (HEART RATE)	164
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	3.3
DEFLECTION AS A % OF $\dot{V}O_2$MAX	72.6
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	5.1
LACTATE - 10 MIN (mM)	4.3
LACTATE - 15 MIN (mM)	7.1
LACTATE - 20 MIN (mM)	5.8
LACTATE - 25 MIN (mM)	7.7
LACTATE - 30 MIN (mM)	5.3
LACTATE - 5 MIN POST (mM)	N/A

SUBJF^T EIGHTEEN

SEX (MALE OR FEMALE)	FEMALE
AGE (YEARS)	27
BODY MASS (KG)	51
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	2.88
$\dot{V}O_2$MAX (ML/KG/MIN)	56.8
$\dot{V}O_2$MAX (WATTS)	210
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	110
DEFLECTION (HEART RATE)	172
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	2.13
DEFLECTION AS A % OF $\dot{V}O_2$MAX	74
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	3.35
LACTATE - 10 MIN (mM)	4.8
LACTATE - 15 MIN (mM)	4.25
LACTATE - 20 MIN (mM)	3.75
LACTATE - 25 MIN (mM)	4.3 INACCURATE SAMPLE (3.5 M/L)
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	

SUBJECT NINETEEN

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	40
BODY MASS (KG)	81
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	4.77
$\dot{V}O_2$MAX (ML/KG/MIN)	59.68
$\dot{V}O_2$MAX (WATTS)	375
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	N/A DID NOT DEFLECT
DEFLECTION (HEART RATE)	N/A
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	N/A
DEFLECTION AS A % OF $\dot{V}O_2$MAX	N/A
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	N/A
LACTATE - 10 MIN (mM)	N/A
LACTATE - 15 MIN (mM)	N/A
LACTATE - 20 MIN (mM)	N/A
LACTATE - 25 MIN (mM)	N/A
LACTATE - 30 MIN (mM)	N/A
LACTATE - 5 MIN POST (mM)	N/A

SUBJECT TWENTY

SEX (MALE OR FEMALE)	MALE
AGE (YEARS)	23
BODY MASS (KG)	79
DATA FROM $\dot{V}O_2$MAX TEST	
$\dot{V}O_2$MAX (L/MIN)	5.58
$\dot{V}O_2$MAX (ML/KG/MIN)	70.6
$\dot{V}O_2$MAX (WATTS)	425
DATA FROM CONCONI TEST	
DEFLECTION (WATTS)	340
DEFLECTION (HEART RATE)	172
DEFLECTION AS A $\dot{V}O_2$ (L/MIN)	4.07
DEFLECTION AS A % OF $\dot{V}O_2$MAX	72.9
DATA FROM PROLONGED CYCLE	
LACTATE - 5 MIN (mM)	4.1
LACTATE - 10 MIN (mM)	3.55
LACTATE - 15 MIN (mM)	3.5
LACTATE - 20 MIN (mM)	3.1
LACTATE - 25 MIN (mM)	3.35
LACTATE - 30 MIN (mM)	3.95
LACTATE - 5 MIN POST (mM)	N/A

APPENDIX F

DESCRIPTION, SPECIFICATIONS AND CRITICISMS OF THE MONARK 829 E CYCLE ERGOMETER.

DESCRIPTION OF EQUIPMENT

The Monark 829 E is an electronically driven friction braked cycle ergometer. The mechanical componentry consists of a steel frame, a balanced flywheel, a belt braking device, and a force measuring pendulum assembly (Monark, n.d.).

"The electronic componentry consists of two microcomputers which function as a single integrated component" (Monark, n.d., p. 6). Monark (n.d.) report that the base controller receives the pedal speed, the externally applied force, monitors the heart rate, and activates a linear motor which adjusts the tension of the braking belt (i.e. regulates the braking force). Monark (n.d.) claim that "the force may be automatically varied in response to changes in pedal speed to maintain a constant power workload" (p. 6). They continue, that the second microcomputer, a hand-held unit, "communicates with the operator via a keyboard and display subsystem" (p. 6). The operator sends commands to the base controller via this second microcomputer.

SPECIFICATIONS OF THE MONARK 829 E.

As per "Monark Instructional Manual"

Brake power	0-350 W at 50 RPM.	
	0-700 W at 99 RPM.	
Power regulation at	50 RPM:	+/- 5 Watts
	40 RPM:	+/- 4 Watts

Computer:

Dual 4 MHz microcomputer system

300/1200 Baud serial communications port

Electrical:

110/220 VAC, 50/60 Hz, 40 W maximum

Low voltage (12v) high isolation wall mount transformer

LITERATURE SEARCH

A search of the literature involving ergometers and exercise testing failed to provide any evidence that the Monark 829 E has or is currently being used. Whether this stems from the fact that the ergometer is relatively new on the market, or that other researchers have found it unsuitable for their purposes, is unknown.

PERSONAL CRITICISMS OF THE MONARK 829 E

The first criticism of the cycle ergometer involves the use of only one point of calibration. Monark advise using a single known mass (i.e. 4 kg) to calibrate the pendulum weight. A further one or two calibration points (weights) could aid in establishing whether there is any error in calibration throughout the range of workloads employed.

The second criticism relates to the period of time taken for the ergometer to adjust to each new workload. When the ergometer was programmed to move to a new pre-set workload there was a minimum period of approximately five seconds before the new workload was attained. Similarly when the subject altered their pedal speed at the present workload the ergometer required approximately five seconds to adjust the belt's tension in order to maintain the constant power output. Whether this significantly affected the subjects performance is unknown, but was of concern and deemed worth considering.

APPENDIX G

Glossary

Individual Anaerobic Threshold (IAT):- Stegmann, Kindermann and Schnabel (1981) cited by McLellan and Jacobs, (1989) consider the IAT to be "the metabolic rate at which the elimination of blood lactate during exercise is both maximal and equal to the rate of diffusion of lactate into the blood". The term was first introduced by Keul and Simon in 1979. Both Stegmann et al.(1981) and Keul and Simon (1979) use tangents fitted to the lactate curve to determine the appropriate threshold.

Steady State Lactate(SSL):- Considered to be the level at which there is a balance between the production and elimination of lactate during exercise of a continuous nature.

Lactate Threshold (LT):- Generally referred to as the highest exercise intensity obtained before an increase in lactate occurs, above resting levels (Henritze, Weltman, Schurrer and Barlow, 1985). The lactate level associated with this threshold usually falls between 1.5 and 2.5 mM.

Macrocycle:- One of the components making up a training plan. It usually consists of four smaller components or segments known as microcycles. A macrocycle is typically four weeks in length.

Maximum Lactate Steady State (MLaSS):- Defined by Heck et al. (1985) as the "maximal balance between lactate production and elimination in continuous exercise" (p. 117). In the present study it has been abbreviated to 'MLaSS', although other researchers have used slight variations when referring to the same state (i.e Haverty et al., 1988, uses MSSLA).

Maximum Oxygen Uptake ($\dot{V}O_2max$):- "The maximal rate at which oxygen can be consumed per minute; the power or capacity of the aerobic or oxygen system" (Fox, Bowers and Foss, 1989).

Microcycle:- One of the components making up a training plan. It is the smallest segment in terms of time, usually being a week in length.

Onset of Blood Lactate Accumulation (OBLA):- The term was first introduced by Karlsson in 1982. He maintains that "this point can be understood as:

1. A sudden increase of the lactic acid blood level as compared to the trend of submaximal load values.
2. An increase in the lactic acid blood level as compared to a standard value (e.g. 2 mM) considered as an indication of basal conditions.
3. A standard value fixed in advance" (Dal Monte, 1988).

Wind Trainer:- A piece of equipment typically used for cycle training indoors, although it does also get used at the track for warming up. It is basically a stand in which the cycle sits, with a small roller that the rear wheel of the cycle rests upon. When the cycle is pedalled it remains stationary with its rear wheel spinning against resistance applied by the roller. The resistance of the roller is usually controlled by small bladed fans attached to the roller itself or by a magnetic system.