DEVELOPMENT OF AN INCREMENTAL

STEP TEST THAT ACCOUNTS FOR LOWER LIMB LENGTH

FOR PEOPLE UNDERGOING REHABILITATION.

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TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

ABSTRACT AND INTRODUCTION

1.1 Abstract

This study developed a multi-stage step test for the prediction of $\dot{V}O_{2peak}$ in people with low tolerance to exercise. The aim was to develop a simple and safe protocol, that accounted for differences in statute height and is suitable for use in exercise rehabilitation. The step height (H_{step}) was determined as 0.125 x the subject's height ($H_{subject}$). People undergoing physical and psychological rehabilitation (n=23) were compared to a normal group (n=28), not undergoing rehabilitation. The symptom-limited step test began at a low cadence (14 cycles per minute, $c.min^{-1}$) and increased by 4 $c.min^{-1}$ to $\dot{V}O_{2peak}$. Peak values for rehabilitation subjects for $\dot{V}O_2$ and heart rate were 27.8 ± 6.2 $ml.kg^{-1}.min^{-1}$ and 168 ± 21 $b.min^{-1}$, respectively. The corresponding peak values for normal subjects were 36.5 ± 6.8 $ml.kg^{-1}.min^{-1}$ and 180 ± 15 $b.min^{-1}$, respectively. Five variables were entered into multiple quadratic regressions, to generate algorithms for the prediction of submaximal and peak $\dot{V}O_2$: age, sex, weight, time and heart rate. Three algorithms were produced "All", "Normal" and "Rehabilitation". They explained 90%, 91% and 94% of the variation in results (r^2 = 0.90, 0.91, 0.94), with standard errors of 2.86, 2.72 and 2.04 $ml.kg^{-1}.min^{-1}$, respectively. It is envisaged that the test will be used to predict functional capacity in people undergoing exercise rehabilitation.

1.2 Introduction

Step Tests have been used for many years to estimate an individual's aerobic power ($\dot{V}O_{2max}$). The present study developed a multi-stage step test for the prediction of $\dot{V}O_{2max}$ in people with low tolerance to exercise. The aim was to develop a protocol that accounted for differences in statute height and is suitable for use in exercise rehabilitation. Step tests are used because they are simple to administer and interpret and do not require expensive equipment, specialised staff or a high degree of skill on the part of the subject. Large numbers of subjects can be tested quickly. However, previously published step test protocols prescribed step heights that are too high for people undergoing exercise rehabilitation (Brouha, 1943; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Tuxworth and Shahnawaz, 1977).

Previously developed step tests have required the subject to step on to a raised surface, of a predetermined height at a set cadence. Generally, heart rate at the end of the work period or during the recovery phase is used to predict maximal aerobic power. A validity problem with most of the existing protocols is that each uses an absolute step height for all people tested. This means that the intensity of the test depends partly on a subject's height and lower limb length. Recognising this deficiency, Francis *et al.* (1987, 1988, 1989, 1991, 1992) prescribed step heights which account for individual statute height and leg length differences. In the present study, statute height was also used to determine step height, but a lower ratio of step height to statute height was used to enable the completion of the testing protocol by rehabilitation subjects. Although step tests are no longer used for the assessment of elite and sub-elite

athletes, they are useful and functional tests in subjects with low levels of fitness, particularly those people undergoing physical rehabilitation.

In this study, four features of the protocol were designed to improve on existing step test protocols for the estimation of aerobic power, particularly in the context of rehabilitation. These were: 1) step height was varied in relation to statute height, 2) an incremental protocol was used which is an advance on single stage tests which predict VO_{2max} from a single measurement of heart rate and work rate, 3) oxygen consumption was measured at each stage in the test; enabling a predictive test of submaximal as well as maximal aerobic power for laboratories not equipped with gas analysis systems, and 4) the subjects for this study were drawn from the same population for which the test will be subsequently used ie. people undergoing physical rehabilitation in whom stepping is functionally important. It is envisaged that the test will be used to assess people undergoing exercise rehabilitation.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Measurement Of Aerobic Power ($\dot{V}O_{2max}$)

Aerobic power is measured as maximal oxygen consumption ($\dot{V}O_{2max}$) and is commonly used to indicate cardiorespiratory fitness (American College of Sports Medicine, 1991). Åstrand and Rodahl (1986) defined maximal aerobic power as being "the highest oxygen uptake an individual can attain during exercise while breathing air at sea level". Analysis of expired gas yields the highest test reliability, accuracy and validity for the measurement of maximal oxygen consumption ($\dot{V}O_{2max}$). In situations where the exercising muscle is less than 50% of the total muscle mass, peak oxygen consumption ($\dot{V}O_{2peak}$), rather than $\dot{V}O_{2max}$ is obtained (Brooks *et al.*, 1996). $\dot{V}O_{2peak}$ is at least a few percent lower than $\dot{V}O_{2max}$. Values of $\dot{V}O_{2peak}$ are easier to obtain in a non-athletic population as it is a safer test to administer.

2.2 Prediction Of VO_{2max}

Direct measurement of $\dot{V}O_{2max}$ is difficult to administer in the field or to a large population (Bonen, 1975; Kasch, 1984; Taylor *et al.*, 1955) and has other disadvantages including equipment requirements and safety. Submaximal tests that are either single- or multi-staged offer the attractiveness of simplicity and safety, often without the requirement of maximal exertion (Francis and Culpepper, 1989). These

tests however, are subject to other concerns regarding reliability and validity. Many test protocols have been developed to predict $\dot{V}O_{2max}$ from either submaximal or maximal work tests. These include step tests, bicycle tests, and tests of walking and running (Appendix A). Most of these tests are based on relationships between heart rate, work rate and oxygen consumption. As work rate increases, heart rate and oxygen uptake increase linearly to their peaks (DeVries *et al.*, 1989; DeVries and Klafs, 1965; Jessup *et al.*, 1974).

Wyndham (1967) stated that submaximal tests use several assumptions when predicting $\dot{V}O_{2max}$. These are that (i) heart rate and oxygen consumption are linear functions of power (except for random variations); (ii) heart rate and oxygen consumption reach asymptotic peak values at similar high level work loads; (iii) if 1 & 2 are correct then heart rate is a linear function of oxygen consumption throughout the range of power, up to an individual's maximum, and (iv) the inter-individual variation in heart rate about the population mean is sufficiently small (if age is accounted for) for the population mean heart rate to be used without inducing large errors. The most common forms of submaximal or maximal tests use cycling (Åstrand and Ryhming, 1954), running (Cooper, 1968), walking (Bruce, 1974) or stepping (Brouha, 1943) modes of exercise.

2.2.1 The Bicycle Ergometer Protocols

Åstrand and Ryhming (1954) developed a nomogram for the prediction of maximal oxygen uptake using a single-stage submaximal bicycle ergometer protocol. It has since become a standard test for predicting $\dot{V}O_{2max}$ (American College of Sports

Medicine, 1991) even though both Jette (1979) and Jessup *et al.* (1974) have found the correlation of actual versus predicted oxygen uptake to be low, thus suggesting a low validity of the test. Leger and Gadoury (1989) reported that the Åstrand-Ryhming test was only moderately accurate in predicting $\dot{V}O_{2max}$ (correlation coefficients ranging from 0.54 to 0.71 for predicted versus direct $\dot{V}O_{2max}$). At the time that the test was developed, Åstrand & Ryhming (1954) acknowledged that validity in older and unfit subjects was unknown.

The Physical Work Capacity (PWC) test (Sjöstrand, 1947) is a multi-stage submaximal protocol and is based on a known relationship between power and oxygen consumption. The PWC_{max} is estimated by extrapolating to maximal heart rate and reading off the corresponding maximal work rate and predicted $\dot{V}O_{2max}$. DeVries and Klafs (1965) reported a correlation coefficient of r = 0.88 for PWC_{max} versus direct $\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$). DeVries *et al.* (1987) developed the PWC further by testing to fatigue. This was used on elderly subjects (DeVries *et al.*, 1989) and was shown to be a reproducible test of PWC to fatigue (r = 0.979). The Physical Work Capacity at 75% of heart rate maximum ($PWC_{75\%}$) (Miyashita *et al.*, 1985) has been reported as a safer alternative to PWC_{max} but the authors questioned its accuracy in the prediction of PWC_{max} and $\dot{V}O_{2max}$.

2.2.2 Walk/Run Test Protocols

Drake *et al.* (1968) proposed that performance of ambulatory endurance exercise could be used to predict $\dot{V}O_{2max}$. At almost the same time, Cooper (1968) collected data for a twelve minute walk/run test and reported a correlation coefficient of 0.897

with predicted $\dot{V}O_{2max}$. Cooper, however sampled from a population consisting of healthy males with an average age of 22 years (age range of 17-52, but most subjects were young). This high correlation coefficient has since been challenged by Jessup *et al.* (1974) who cited a correlation of only 0.34. However, due to the homogeneous group of subjects that were studied, this could explain the low correlation. Leger and Gadoury (1989), when reviewing the literature for the relationship between the performance 12 minute run/walk test and $\dot{V}O_{2max}$, reported a range of correlation coefficients from 0.34 to 0.90.

In a series of studies by Leger *et al.* (1980, 1982, 1984, 1989) the validity and reliability of different running protocols were investigated. Leger and Boucher (1980) reported a high validity for the prediction of $\dot{V}O_{2max}$ from the performance of the Universite de Montreal Track Test (UM-TT) ($r = 0.96$, compared to a maximal treadmill test to determine $\dot{V}O_{2max}$). The authors also reported a high reliability ($r = 0.97$) between repeated UM-TT performances. From this work, a multi-stage 20m shuttle run protocol was developed by Leger and Lambert (1982) with a correlation coefficient of 0.84 (predicted versus actual $\dot{V}O_{2max}$). The test was improved ($r = 0.9$) by Leger and Gadoury (1989) using stages of (approximately) one minute.

2.2.3 Step Tests

As a predictor of $\dot{V}O_{2max}$, most step test protocols have yielded high reliability coefficients but variable validity coefficients (Watkins, 1984). Meyers (1969) pointed out that tests must be reliable if they are to be valid, though reliability[1] does not

[1] Reliability is the "degree of consistency of a test." Thomas & Nelson (1990).

guarantee validity[2]. Tests may be single- or multi-staged, though the majority are single-stage.

The first published step test was devised by Master and Oppenheimer (1929) and this was the precursor of the widely-used Harvard Step Test (HST) (Brouha, 1943). Brouha worked on the basis that fitness could be estimated by exposing the subjects to a test that could be performed in a steady-state for no more than a few minutes. The HST uses a very high step of 50.8 cm for males and a fast stepping cadence of 30 cycles per minute ($c.min^{-1}$) for up to 5 minutes. Datta *et al.* (1974) reported that due to the combination of the step height, cadence and duration, only four subjects of 16 were able to complete the test and contended that most subjects were limited by local muscle fatigue. Of the four who completed the test, three were aged in the low twenties and all were involved in some form of athletic training, compared to the mean age of the group of 30 years, with half of the group being sedentary.

Modifications to the original HST protocol have included decreasing the step height and cadence of stepping and the duration of the test (Bailey *et al.*, 1976; Davis and Wilmore, 1979; DeVries *et al.*, 1965; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Siconolfi *et al.*, 1985; Tuxworth and Shahnawaz, 1977; Witten, 1973). In the able-bodied population, the highest correlations with direct $\dot{V}O_{2max}$ were obtained with step heights of no more than 40 centimetres, a stepping cadence in the range of 20 to 25 $c.min^{-1}$ and duration in the range of 3 to 5 minutes (Francis, 1987; Watkins, 1984). In contrast to the HST, Tuxworth and Shahnawaz (1977) reported that all of their 400 subjects completed a test which used a 40 cm step height with a cadence of 15 and 25

[2] Validity is "whether the results can be attributed to the experimental variables rather than the extraneous variables and whether the results can be generalised beyond the particular experiment." Thomas & Nelson (1990).

$c.min^{-1}$ in two separate 5 minute bouts. However in this study, the test group was young and fit (23 to 41 year-old males), and could be expected to cope with the prescribed work intensities with less difficulty than for the population studied in the present research. Variations in step height were used by Shapiro *et al.* (1976) by using a constant stepping rate of 25 $c.min^{-1}$ for 6 minutes using bench heights of 25, 32.5, and 40 cm.

A common problem with all of these studies, including that of Shapiro *et al.* (1976), is that the step height was not adjusted to account for body dimensions, particularly leg length. A shorter subject is disadvantaged in protocols that prescribe absolute step heights, because the range of movement of the hip and knee joints is greater. As a consequence, the work done (relative to body weight) will be greater for a shorter subject than a tall one. Since the cadence is prescribed in each test, this means that power and the oxygen cost of stepping on to a *relatively* higher step is expected to be greater (Culpepper and Francis, 1987).

2.3 Step Height : Body Dimension Ratios For Step Tests

2.3.1 Bone Measurement Techniques

Green *et al.* (1946) used orthorentgenograms to establish a direct measure of the true length of each bone of the lower extremity. Anderson and Green (1948) described the femur length as the distance from the top of the capital epiphysis to the most distal portion of the lateral condyle. In association with the direct measurement of the tibia,

this seemed to be the most accurate measure of the weight bearing length of the lower extremities. They also found that the femur:functional height ratio was 0.2626 for females and 0.2672 for males. These values were obtained from a random selection of Americans. It is assumed that these ratios will be similar in Australians. This is the only published data on this relationship and has been adapted, along with the work by Culpepper and Francis (1987), for use in this thesis.

2.3.2 Step Height : Leg Length Ratio

The rationale for adjusting the step height to leg length has been outlined in studies by Datta *et al.* (1974), Elbel and Green (1946), Ariel (1969) and in particular, a series of studies by Francis *et al.* (1987, 1988, 1989, 1991, 1992). These studies indicated that a more accurate prediction of $\dot{V}O_{2max}$ is achieved in step testing when a fixed ratio of step height to leg length is used (r = 0.7 to 0.98). Adjustment of the step height using leg length measurements has the effect of normalising the prescribed work, and gives a better indication of true $\dot{V}O_{2max}$. Surprisingly, Cicutti *et al.* (1991) found that there was no significant difference between $\dot{V}O_2$, heart rate and $\dot{V}_E$ when stepping at 30, 40, and 50% of leg length in a study on young boys 8-12 years of age. One can only assume that the differences in step heights for these young subjects was not great enough to evoke graded physiological responses, or their results were confounded by measurement error or large inter-individual differences.

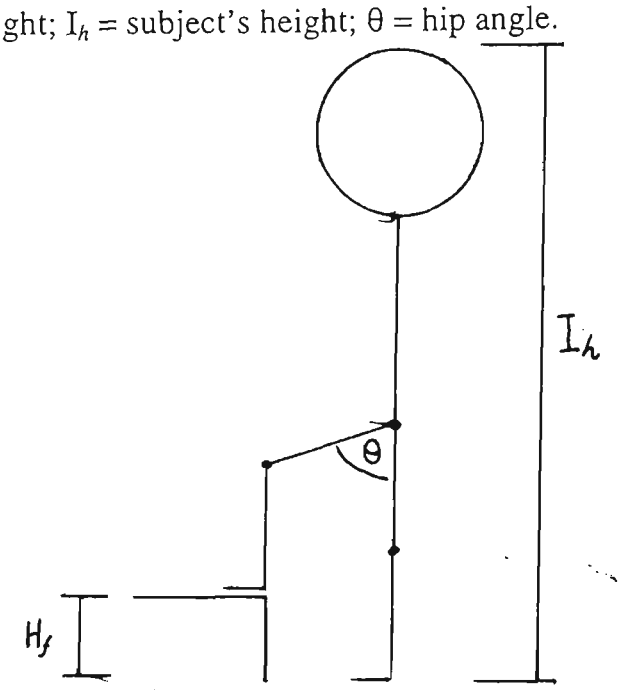
Culpepper and Francis (1987) used the data of Anderson and Green (1948) and Anderson *et al.*(1978) as the basis for constructing an algorithm for determining the

ideal step height. They began by reviewing the literature (Davis and Wilmore, 1979; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Tuxworth and Shahnawaz, 1977) to find the *absolute* step height associated with the greatest correlation between predicted and direct $\dot{V}O_{2max}$. From the *absolute* step heights and the average height of the subjects in these earlier studies, and by using the ratio of femur length to body height (Anderson and Green, 1948), they were able to estimate the angle of the hip joints for the various step heights. Leg length was estimated from the height of the subject and the application of the algorithm (Anderson and Green, 1948), rather than by direct measurement of leg length, because the error of measurement was assumed to be higher for the measurement of leg length than statute height. They then produced the following algorithms to determine the "ideal" step height based on the individual's height:

Females: $H_f = (0.2626 \times I_h)(1 - \cos\theta)$.

Males: $H_f = (0.2672 \times I_h)(1 - \cos\theta)$.

where: H_f = step height; I_h = subject's height; θ = hip angle.



(Adapted from Culpepper and Francis, 1987)

After devising these algorithms, they them applied them to previous published work (Davis and Wilmore, 1979; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Tuxworth and Shahnawaz, 1977) to estimate hip angles. Culpepper and Francis (1987) then categorised the hip angles derived from these other studies into four quartiles (65^0, 73.3^0, 81.7^0 and 90^0), and then reviewed the physiological data. They concluded that the best correlation with true $\dot{V}O_{2max}$ was obtained with an average hip angle of 73.3^0. Solving their equations for a hip angle of 73.3^0, the algorithms were simplified to:

Females: $H_f = 0.189 \times I_h$.

Males - $H_f = 0.192 \times I_h$.

The usefulness of these algorithms is to normalise the anatomical differences associated with height.

2.3.3 Step Tests Using a Fixed Step Height : Leg Length Ratio

Francis *et al.* (1987, 1988, 1989, 1991, 1992) conducted a number of studies using the algorithms (see Section 2.3.2). Francis and Culpepper (1989) administered a step protocol of 30 $c.min^{-1}$ at a step height of 0.189 x standing height, for 3 minutes, and then measured a 15 second post exercise recovery heart rate and correlated their findings with $\dot{V}O_{2max}$ determined by gas analysis, using the Bruce treadmill protocol. Francis *et al.* (1988, 1989, 1991, 1992) used three protocols which were compared to direct $\dot{V}O_{2max}$. A test duration of 3 minutes was used for each. Only the cadence was varied (22, 26 or 30 steps per minute [$c.min^{-1}$]). In all of these studies there was a high correlation (average r = 0.76) between the predicted and the actual $\dot{V}O_{2max}$, with the

highest correlation being for 26 $c.min^{-1}$ ($r = 0.80$). The standard error of estimates of $\dot{V}O_{2max}$ were relatively small, on average within ± 5.9% of the actual values; this was considerably better than the standard errors for the Åstrand-Ryhming (1954) bicycle ergometer test (average = ± 9.62%) and the McArdle *et al.* (1972) step test (average = ± 16%). The authors concluded that the height-adjusted step test is an improvement over fixed height step tests (Francis and Feinstein, 1991). In pilot work for the present study however, four rehabilitation subjects were unable to complete the test at the heights prescribed by Francis *et al.* (1987, 1988, 1989, 1991, 1992) without the onset of pain. Therefore, in the main study, the step height : statute height ratio was reduced, and in order to compensate for this, weights were added in the latter minutes of the protocol in order to reach $\dot{V}O_{2max}$.

2.4 Exercise Tests And Special Populations

Ascending and descending steps is functionally important exercise in most rehabilitation programs. This provides a rationale for developing a step test that is relevant to the exercise rehabilitation industry. Another rationale is that stepping requires little skill and equipment and is easy to administer and interpret, and is, therefore, useful to rehabilitation therapists who are normally not trained in the exercise sciences.

2.4.1 Cardiac Rehabilitation

Step tests have sometimes been used in cardiac rehabilitation, based on the original work of Master and Oppenheimer (1929) which is a subjective step test for exercise

tolerance where systolic blood pressure and heart rate are measured during exercise and recovery. The outcome of the test is subjective in that blood pressure and heart rate are monitored for two minutes following exercise and should have returned to near pre-exercise levels by this time. In sub-clinical situations, it was helpful in the assessment of circulatory efficiency. However, Constant (1980) calculated that the aerobic power required to complete this test is of the order of 5 to 6 METS, which is several-fold more intense than some cardiac rehabilitation patients could sustain for even a few minutes. This suggests that the Master and Oppenheimer test may be unsuitable for most cardiac rehabilitation patients.

2.4.2 Other Exercise Rehabilitation

There is very little published work on the application of step tests to rehabilitation, yet stepping exercise is widely used as an exercise modality both in rehabilitation and in activities of daily living. Singh *et al.* (1992, 1994) used a shuttle walk protocol to determine disability in chronic airways obstruction. Based on the work by Leger and Lambert (1982), they used a multi-stage incremental shuttle test to reveal cardiovascular limitations. Singh *et al.* (1992) argued that the shuttle test allowed for measurement of functional capacity and limitations for exercise. Comparisons between $\dot{V}O_2$ during the shuttle walk test and a modified Balke treadmill in which the subjects reached a symptom-limited maximum in 6 minutes were made by Singh *et al.*(1994). The researchers claimed that $\dot{V}O_{2max}$ (treadmill test) correlated with distance covered (shuttle walk test) at 0.88. However as the treadmill test was symptom-limited, the end point of the test was $\dot{V}O_{2peak}$, rather than $\dot{V}O_{2max}$. Pitetti *et al.* (1987) compared four arm ergometer exercise protocols for the prediction of

maximal work capacity in paraplegics. Maximal exercise responses were elicited in paraplegics with arm ergometer exercise. This result, however is confined to only a small group within the rehabilitation population and hence this protocol is not suitable for a vast number of subjects.

In a pilot investigation conducted by the Australian Commonwealth Rehabilitation Service (unpublished data, 1993) on 430 of their clientele it was found that over 40% suffered from various forms of back ailments while a large group suffered from multiple orthopaedic problems. Using a step height of 20 cm for all subjects regardless of leg length, 80% of subjects were able to complete a single-stage three minute test at 24 $c.min^{-1}$. The investigators did not measure oxygen consumption and so their data could not be used to predict submaximal or maximal VO_2.

2.4.3 Elderly Subjects

In older adults, there will be some similarities in functional capacity with subjects undergoing rehabilitation. This implies that a protocol developed for rehabilitation subjects may have application in healthy populations of elderly people. Amundsen *et al.* (1989) investigated an exercise training program for elderly women assessing them by a step test protocol. DeVries *et al.* (1989) used the PWC to fatigue test in elderly subjects as a more feasible protocol that was of a lower intensity than that required to take the subject to $\dot{V}O_{2max}$.

2.5 Summary

Very few rehabilitation clients use cycling as either a means of transport or as a means of increasing their physical capacities, whereas walking and stepping exercise are common daily tasks. Stepping exercise is functionally important in a rehabilitation program and many physiotherapists, occupational therapists and remedial physical educators wish to assess their clients using step tests and to prescribe stepping exercise. However most existing step tests are unsuitable for rehabilitation clients because they prescribe step heights and cadences that are too severe. Furthermore most prescribe step heights in absolute terms rather than relative to the person's body dimensions. A tall person has a physiological advantage over a short person when stepping onto a fixed height bench (Culpepper and Francis, 1987). The greater physiological efficiency for a tall person results in lower oxygen consumption and casts doubt over test validity.

The *first objective* of this study was to develop a safe, valid test for assessing aerobic power in rehabilitation. This was done in two stages (i) to test a group of rehabilitation subjects up to maximal intensity in a controlled laboratory setting after obtaining medical clearance to conduct these tests; (ii) to compare these results to those obtained in age-matched normal volunteers and (iii) to develop algorithms so that a submaximal version of the maximal test can be used by personnel employed in the rehabilitation industry while not compromising safety, reliability and validity.

In the series of studies by Francis *et al.* (1987, 1988, 1989, 1991, 1992), the step height:leg length ratio was too high to enable people undergoing rehabilitation to

safely complete the test. The *second objective* of this study was to modify this approach by using a lower step height:leg length ratio that will enable over 95% of all types of rehabilitation clients to undertake the test to obtain an estimation of aerobic power.

Most other published methods for predicting aerobic power have been based on research performed on able-bodied and, often, athletic populations. This makes these tests unsafe and unsuitable for use in rehabilitation populations and compromises their validity. The *third objective* was to collect data on people presently undergoing rehabilitation and compare these results to those of the normal subjects.

2.6 Aims Of The Study

2.6.1 General

1. To develop a submaximal multi-stage step test to predict aerobic power in people undergoing physical rehabilitation.

2.6.2 Specific

1. To measure $\dot{V}O_2$ using expired air gas analysis at each minute of a multi-stage step test up to $\dot{V}O_{2peak}$, in healthy volunteers and people undergoing exercise rehabilitation.

2. To develop algorithms to predict submaximal and maximal oxygen consumption using simple measures of age, sex, weight, heart rate and perceived exertion.

CHAPTER THREE

METHODOLOGY

3.1 Subjects

Male and female volunteers (n = 23) who were currently undergoing physical and psychological exercise rehabilitation with the Australian Commonwealth Rehabilitation Service were compared with an age-matched group of male and female volunteers (n = 28) not undergoing treatment for an injury or illness. All subjects completed a cardiovascular risk factor form and an informed consent (Appendix B). Rehabilitation volunteers and subjects over 35 years of age were required to obtain medical clearance to participate. Ethical approval to conduct the study was obtained from the Victoria University Human Research Ethics Committee.

3.2 Procedures

Subjects were weighed on a August Sauter E 1200 electronic scale (calibrated to ± 0.005 kg); height was measured on a stadiometer (calibrated to ± 0.25 cm), skin fold measurements were taken using a skin fold calliper (John Bull British Indicators Ltd., England. Calibrated to ± 1 mm) measuring the sum of eight sites. Blood pressure was measured prior to the commencement of exercise for safety, using an aneroid sphygmomanometer. Bilateral leg length, anterior superior iliac spine (ASIS) to medial malleolus (MM), was measured on a tailor's tape (calibrated to ± 0.1 cm).

ASIS to MM was measured as in field situations this was the easiest site to measure leg length (average of the left and right ASIS to MM was reported). All measurements were recorded by the same operator. The height of the step (H_{step}) was determined as 0.125 x subject's height ($H_{subject}$). The custom-made step platform could be raised or lowered to within ± 0.5 cm of the desired step height.

Each subject was required to perform a warm-up prior to the commencement of the exercise test. This warm-up included a five minute gentle cycle on a Monark ergometer at 25 watts. The subject was then instructed on the stepping technique and given one minute familiarisation stepping at the lowest cadence of 14 cycles per minute ($c.min^{-1}$).

During each step test, heart rate and rhythm, expired air and perceived exertion (Borg Rating Scale of Perceived Exertion (RPE), Borg, 1982) were measured in all subjects. Subjects were monitored for three minutes prior to the commencement of exercise to obtain pre-exercise data. Perceived exertion was measured at the end of every minute of the test. An electrocardiograph (Mortara X-Scribe Stress Test System, Model SCF), was used to record heart rate (every minute), and continuously monitor rhythm and ST-segment. In the case of people over 35 years and those with significant cardio-respiratory risk factors, a 12-lead ECG was recorded; for others, a 6-lead configuration (ie I, II, III, aVR, aVL and aVF) was used.

$\dot{V}O_2$ was measured using open circuit spirometry. The subjects breathed through a two-way non-rebreathing valve (Hans-Rudolf, USA) and expired air was sampled in a mixing chamber before being passed through a ventilometer (Flow Control RL

Applied Electrochemistry Ametek, USA). Samples of the expired air were drawn from the mixing chamber and directed through oxygen (Ametek Applied Electrochemistry S-3A/11, USA) and carbon dioxide (Ametek Applied Electrochemistry CD-3A, USA) analysers. The analysers and the ventilometer were calibrated just prior and immediately following each exercise test, using standard gases (ß standard, BOC Gases) for oxygen (15.88 ± 0.2%) and carbon dioxide (4.93 ± 0.1%) and a calibrated three litre syringe (Hans Rudolph Inc.). $\dot{V}O_2$ ($l.min^{-1}$ and $ml.kg^{-1}.min^{-1}$) and respiratory exchange ratio (RER), were calculated after each 15 seconds, using standard equations (Consolazio *et al.* 1963). All subjects were monitored for three minutes pre-exercise to allow them to familiarise with the equipment, and for five minutes post-exercise to monitor recovery. Subjects wore a nose clip to occlude nasal breathing during the test.

After the three minute pre-exercise resting period, the step test protocol commenced with a cadence of 14 cycles per minute ($c.min^{-1}$) for the first minute. One cycle represented one complete ascent and descent. A Metrina Zen-On Quartz electronic metronome (Zen-On Music Co. Ltd., Tokyo) was used to maintain an accurate cadence. Cadence was incremented at a rate of 4 $c.min^{-1}.min^{-1}$ up to a peak cadence of 34 $c.min^{-1}$. If peak oxygen consumption ($\dot{V}O_{2peak}$) was not reached at this cadence, two kilograms of lead weight (in 0.5 kg ingots) were then added to a vest or belt worn by the subject each minute until peak was achieved or a total test duration of 16 minutes was elapsed.

The criteria for the cessation of the exercise protocol were as follows:

1. The subject wished to stop.

2. The subject experienced chest pain (typical of angina), shortness of breath or any other related pain.

3. Abnormal changes were detected in the subjects ECG (indicating rhythm, conduction and/or perfusion disturbances).

4. The subject perceived they are working maximally (ie. perceived exertion reaches 20 on the Borg scale).

5. The subjects respiratory exchange ratio reached 1.20.

6. The subject had reached $\dot{V}O_{2max}$ (indicated by no further increases in $\dot{V}O_2$ for three successive minutes).

7. The subject completed the test time of 16 minutes.

The test was deemed to have been completed when one of the above criteria for stopping became evident. Recovery data was only measured to monitor the subjects' return towards pre-exercise levels and played no part in the development of the sub-maximal test.

RECOVERY PROTOCOL:

Time (post exercise)	Stepping Frequency ($c.min^{-1}$)	Load (kg)
1	22	0
2	22	0
3	18	0
4	18	0
5	0	0

Table 3.1: Step test recovery protocol.

3.3 Reliability

A reliability study was conducted on a number of normal subjects (n = 6). Subjects were required to perform the full step test on two occasions. The trials took place one week apart and required the subjects to maintain their normal lifestyle throughout.

Subjects were encouraged to perform the same exercise the day prior to the testing on both occasions. The re-test took place at the same time of day for all subjects to account for diurnal variations. The raw submaximal and peak data ($\dot{V}O_2$ and heart rate) and subsequent predicted data were compared.

3.4 Statistics

The variables of age, sex, weight, time, heart rate, sum of skinfolds and Borg ratings of perceived exertion were entered into multiple quadratic regression analyses (SPSS for Windows. Release 6.0, Microsoft, USA. 1993) with direct measurements of oxygen consumption as the dependent variable. The analyses then rejected or accepted variables, according to whether they added to the strength of the prediction. To allow for interactions between variables, linear and quadratic terms were entered in to the regression analyses. The process was repeated for the rehabilitation, normal and combined groups of subjects. The output from each regression analysis listed the independent variables that contributed significantly to the prediction equations. The output also included the coefficients of each independent variable that made up each regression equation (algorithm) and the strength of prediction (r^2). Altogether, there were three algorithms produced: "Rehabilitation", "Normal" and "All".

The three algorithms were compared to one another and the direct measurement of $\dot{V}O_2$ by one way ("algorithm") analysis of variance (ANOVA) with repeated measures. The repeated measures (time) was limited to six minutes; this was chosen because 19 of 23 rehabilitation subjects and 27 of 28 normal subjects were able to complete the first six minutes of the protocol. A further rationale for choosing six

minutes is that this is the length of the submaximal protocol that will be adopted in the application of the research in exercise rehabilitation. In the event of significant differences between algorithms, post-hoc analysis (Tukey test for comparison of pairs of means) was performed to identify where the statistical differences lay.

A two-tailed Student t-test was used to analyse the test-retest (reliability) data. Pearson correlation coefficients were also calculated.

A two-tailed Student t-test was used to analyse the correlation between predicted and direct $\dot{V}O_{2max}$ data. Pearson correlation coefficients were also calculated.

A p value of 0.05 was used as the arbitrator of significance. Results are reported as mean ± S.D. for all directly measured values and mean ± S.E.M. for all predictive values.

CHAPTER FOUR

RESULTS

4.1 Subjects

4.1.1 Subject Characteristics

Characteristics of the subject groups are shown below in Table 4.1.

	Rehabilitation	Normal	Combined
Age (years)	37 ± 9	34 ± 12	35 ± 11
Mass (kg)	76.3 ± 16.7	71.3 ± 11.5	73.5 ± 14.2
Sum of 8 skinfolds (mm)	158.3 ± 55.8	139.5 ± 41.7	149.4 ± 49.9
Height (cm)	172.5 ± 8.9	171.0 ± 9.4	171.7 ± 9.1
Leg Length (cm)	91.1 ± 5.6	90.7 ± 5.6	90.9 ± 5.5
Step Height (cm)	21.6 ± 1.2	21.4 ± 1.2	21.5 ± 1.2

Table 4.1: Subject characteristics

The ranges of values for all the descriptive values were: age: 19-61 years, weight: 50 - 107 kg, skinfolds: 60 - 251 mm, height: 158.2-190.7 cm, leg length: 82 - 108 cm.

The Rehabilitation group (n = 23) comprised of 18 males and 5 females, while the Normal group (n = 28) comprised of 15 males and 13 females.

The correlation which was obtained between leg length and statute height was r = 0.91 (Figure 4.1.).

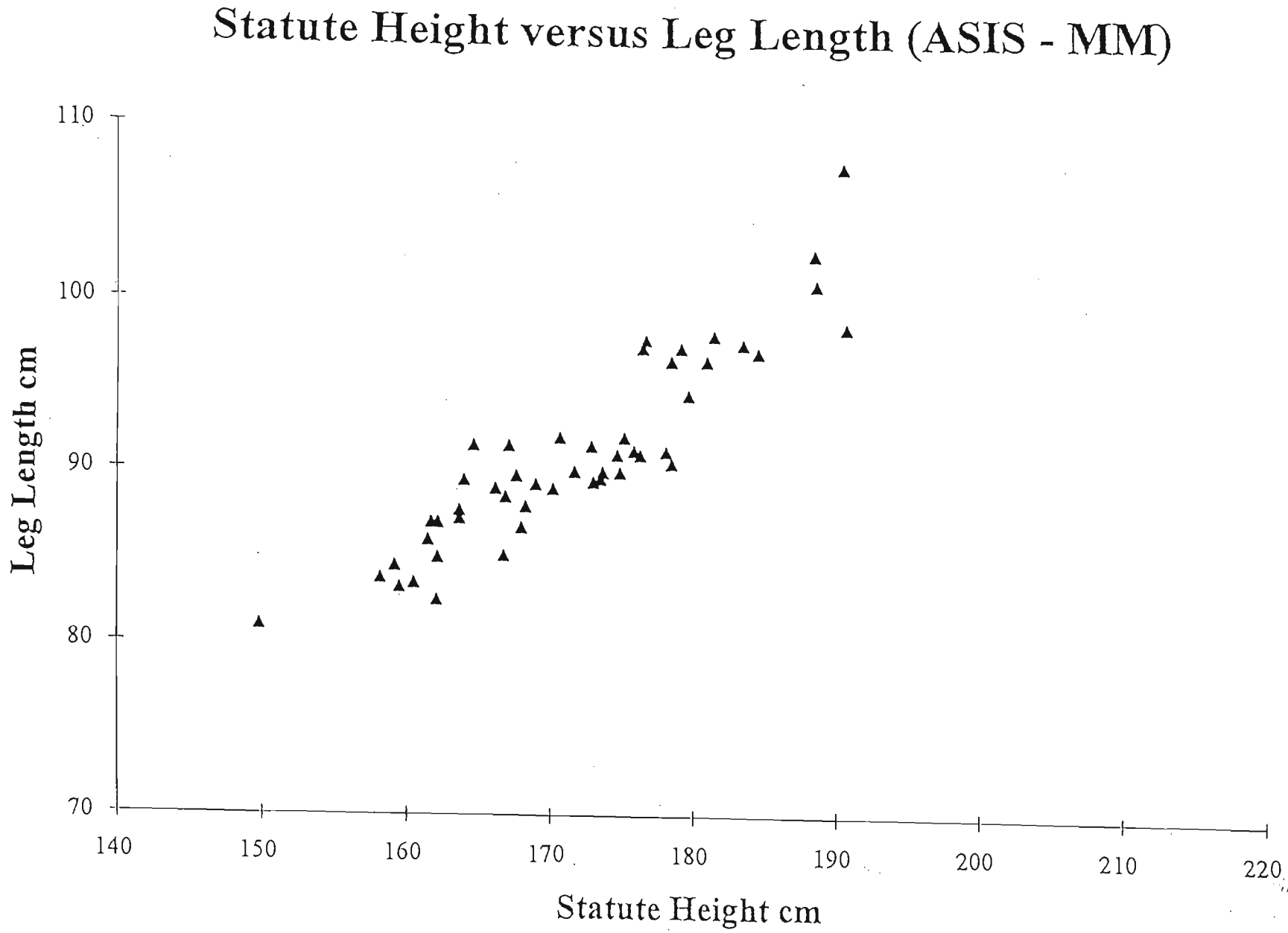


Figure 4.1. Statute height (cm) versus leg length (cm), measured as ASIS - MM (see Methods p.18 for details). ($r = 0.91$, $p < 0.001$)

4.1.2 Rehabilitation Medical Conditions

The conditions reported by the doctors on the rehabilitation subjects (n = 23) and data from the informed consent forms are listed in Figure 4.2. The most abundant condition was chronic lower back pain (48%).

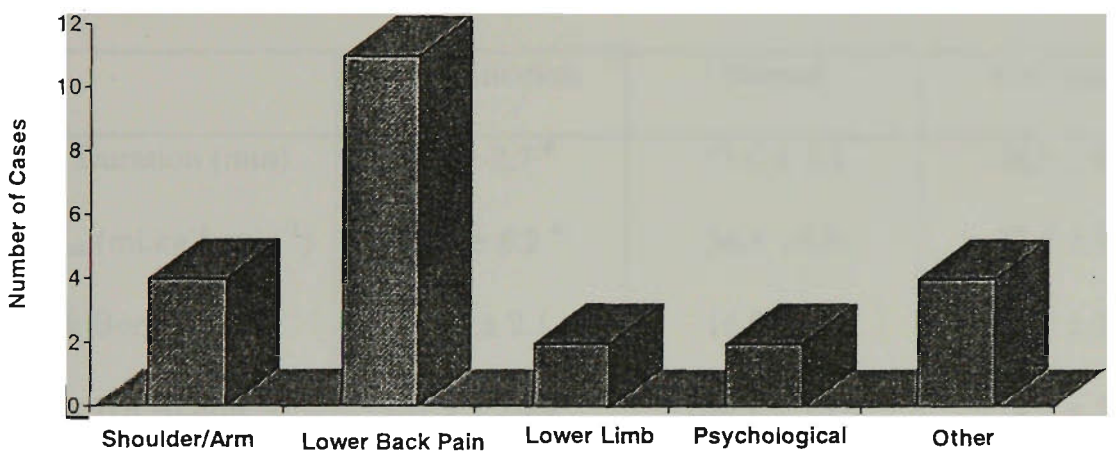


Figure 4.2: Medical conditions of the rehabilitation subjects

4.1.3 Prescribed drugs

Drugs play a large role in the treatment of some of the rehabilitation subjects and these may have an effect on heart rate. Of these subjects 10 (44%) were on some form of prescribed medication (Table 4.2.).

Type	Analgesic	Heart Function	Diuretic	Steroid	Psychological
Number of Drugs *	4	1	2	1	3

* In some instances a single individual was prescribed more than one drug.

Table 4.2: Number of drugs prescribed for the rehabilitation subjects.

4.2 Direct Measurements

4.2.1 $\dot{V}O_{2peak}$ and the peak values for heart rate, Borg rating and RER

The peak effort data are presented in Table 4.3.

	Rehabilitation	Normal	Combined
Test Duration (min)	7.7 ± 2.7 #	13.0 ± 3.9	10.6 ± 4.3
$\dot{V}O_{2peak}$ (ml.kg^{-1}. min^{-1})	27.8 ± 6.2 #	36.5 ±6.8	32.6 ± 7.9
Peak Borg (points)	17.7 ± 2.1	16.9 ±1.9	17.3 ± 2.0
Peak HR (b.min^{-1})	167.9 ± 20.9 *	180.1 ± 15.4	174.6 ± 18.9
Peak HR % (% of 220 - age)	91.9 ± 11.9	96.8 ± 6.6	94.6 ± 9.6
Predicted Maximal HR (b.min^{-1})	183 ± 9	186 ± 13	185 ± 11
Peak RER	1.16 ± 0.12 #	1.09 ± 0.09	1.12 ± 0.11

* $p < 0.05$; # $p < 0.01$ (t-test for independent means; rehabilitation compared to normal group).

RER = Respiratory Exchange Ratio.

Table 4.3: Peak VO_2, heart rate, RER and Borg RPE for rehabilitation, normal and combined groups.

Figures 4.3, 4.4 and 4.5 present the heart rates for the rehabilitation, normal and combined groups against time during the stepping tests. Heart rates reached plateaus in subjects who exercised for greater than ten minutes.

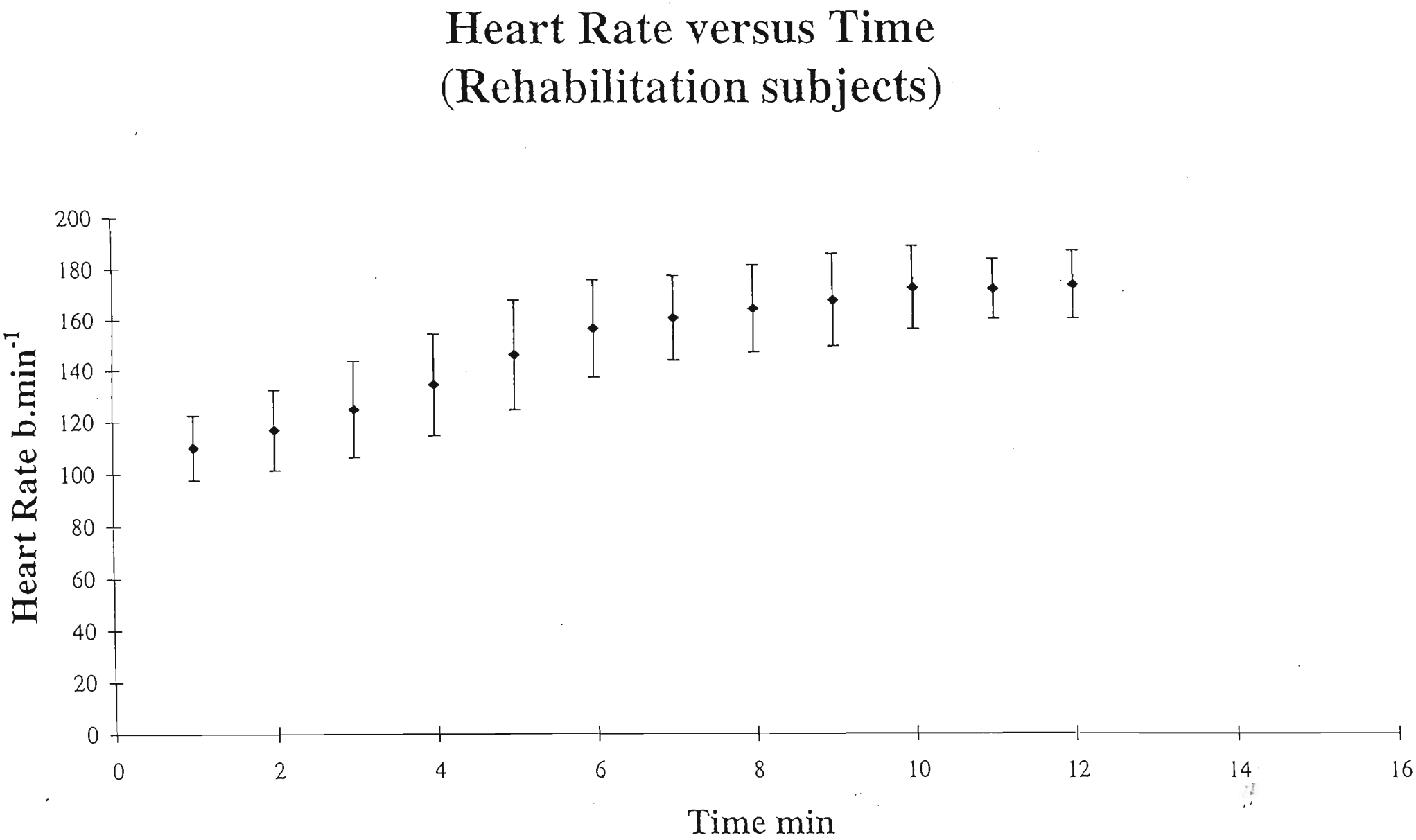


Figure 4.3: Rehabilitation subjects heart rate $b.min^{-1}$ (mean ± sd) versus time min.

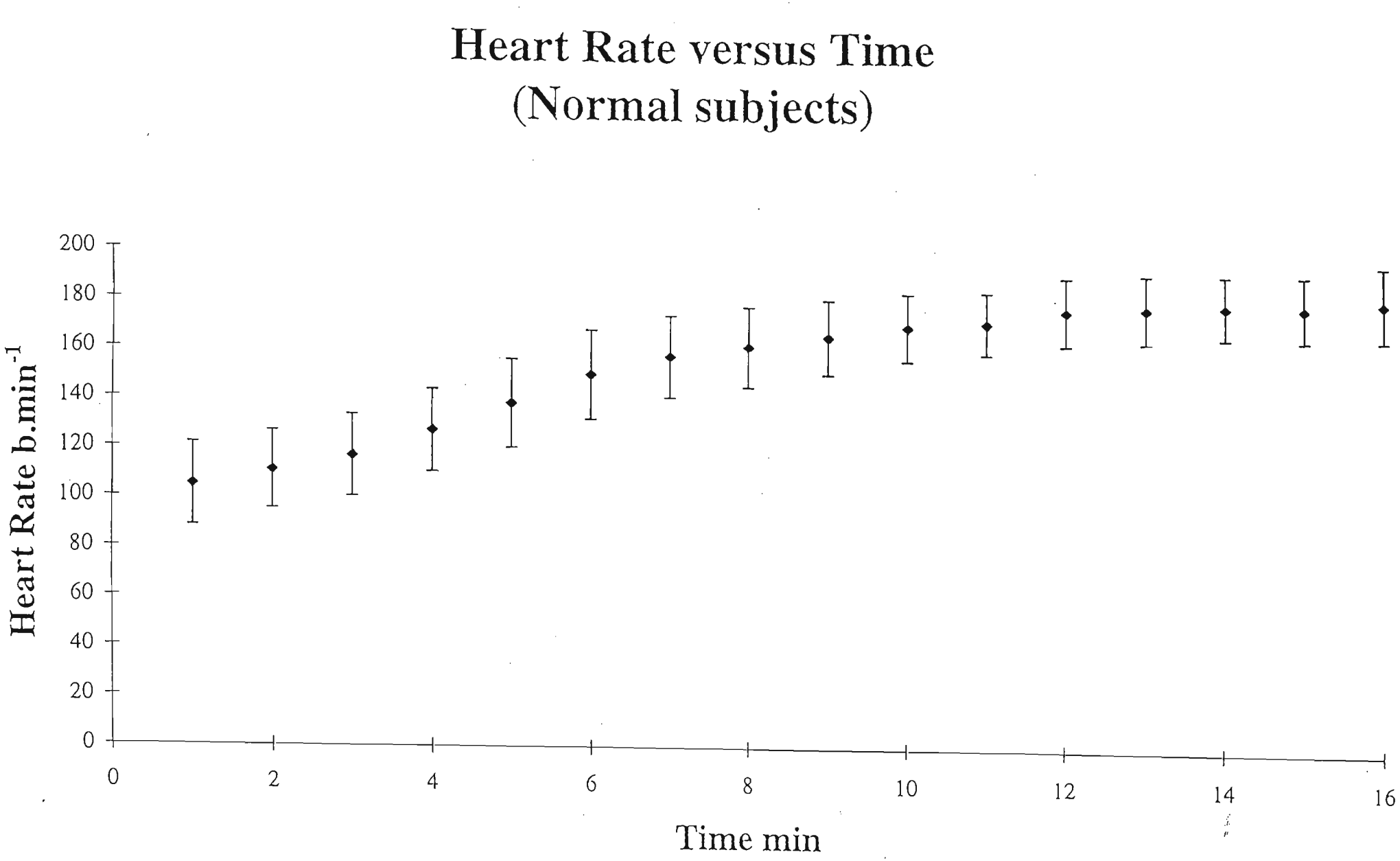


Figure 4.4: Normal subjects heart rate $b.min^{-1}$ (mean ± sd) versus time min.

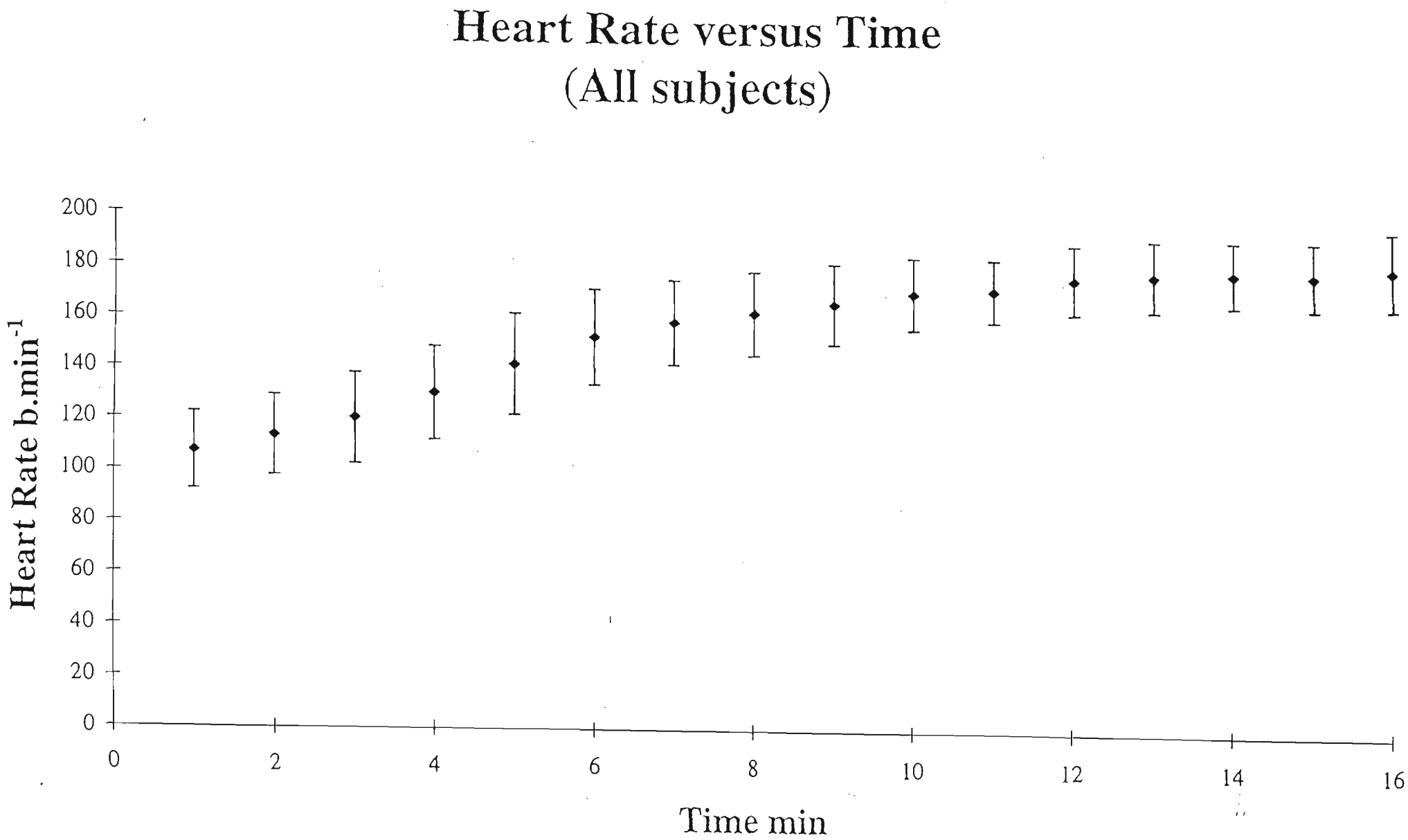


Figure 4.5: Combined groups heart rate b.min^{-1} (mean ± sd) versus time min.

Direct $\dot{V}O_2$ was plotted against time during the progressive stepping tests for rehabilitation, normal and combined groups in Figure 4.6, 4.7, 4.8 respectively. The standard deviations were lower for the first six minutes than for the remainder of the test (except for the last data point for the rehabilitation group, where the only two remaining subjects had an almost identical $\dot{V}O_2$, Figure 4.7). $\dot{V}O_2$ reached a peak in rehabilitation subjects after 10 minutes, but not in normal subjects.

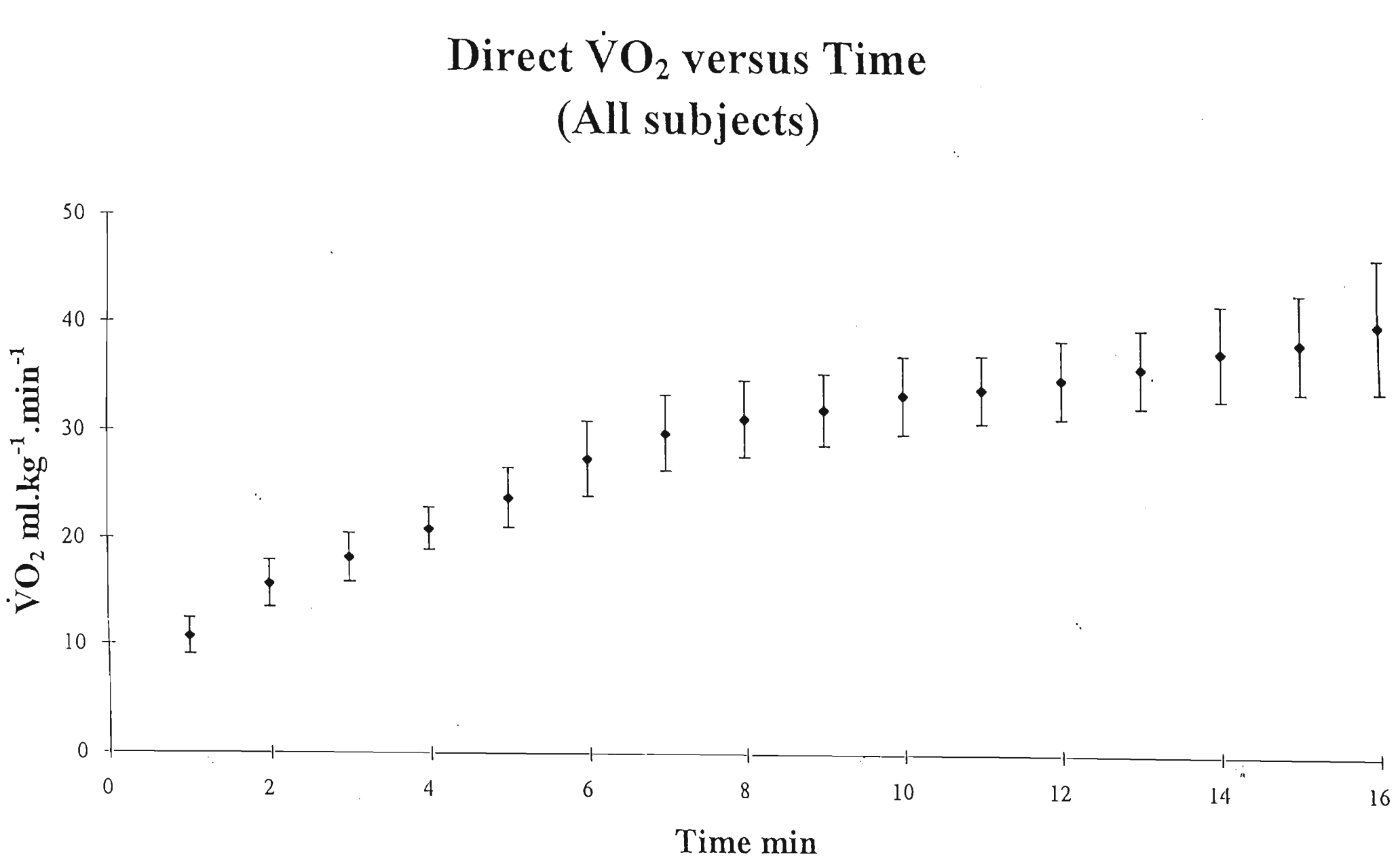


Figure 4.8: Combined groups directly measured $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}) (mean ± sd) versus time (min)

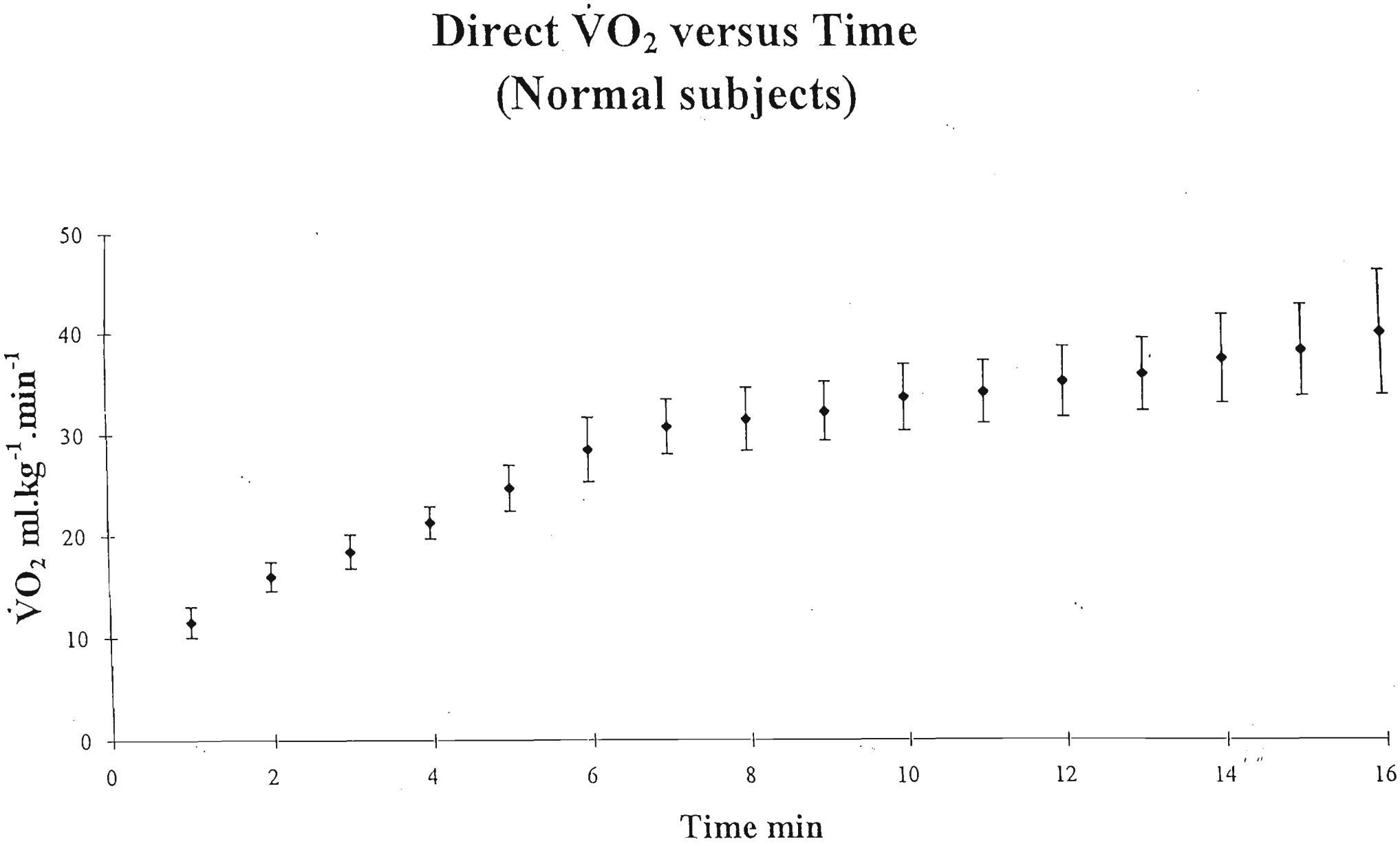


Figure 4.7: Normal subjects directly measured $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}) (mean ± sd) versus time (min)

Direct $\dot{V}O_2$ versus Time (Rehabilitation subjects)

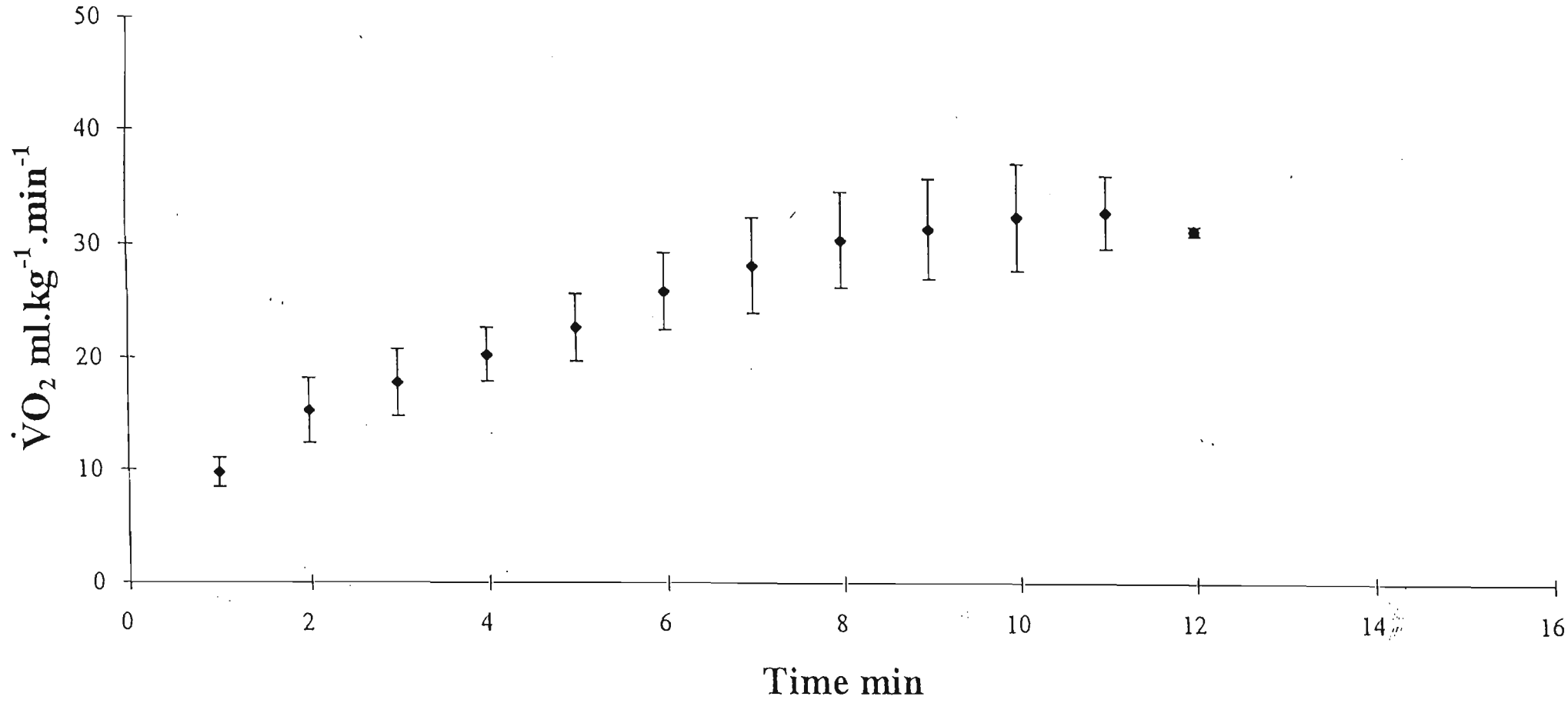


Figure 4.6: Rehabilitation subjects directly measured $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}) (mean ± sd) versus time (min)

4.3 Algorithms for predicting $\dot{V}O_2$

4.3.1 Derivation of algorithms

Multiple quadratic regressions, based on the linear variables of age sex, weight, heart rate and time, and their quadratic transformations, were derived for the prediction of $\dot{V}O_2$ for the rehabilitation, normal and combined groups, and are given below. The regression equations have been designated as "Rehabilitation", "Normal" and "All" algorithms, respectively. The statistical data associated with each is summarised in Table 4.4.

	Rehabilitation	Normal	All
r^2	0.94	0.91	0.90
F	133.33	196.23	269.15
alpha of F value	0.001	0.001	0.001
SEM ($ml.kg^{-1}min^{-1}$)	2.04	2.72	2.86

Table 4.4. The statistical information on the algorithms including r^2, F value, alpha of the F value and standard error of the mean.

Predicted $\dot{V}O_2$ for each of the three algorithms is plotted against the directly measured $\dot{V}O_2$ (Figures 4.9, 4.10 and 4.11). The "All" algorithm (Figure 4.9) shows a tight grouping for both rehabilitation and normal subjects. This graph is seen to plateau for $\dot{V}O_2$ > 35 to 40 $ml.kg^{-1}.min^{-1}$. The "Rehabilitation" algorithm (Figure 4.10), while exhibiting a similar plateau, suggests an under-prediction of $\dot{V}O_2$ for several normal subjects, indicated by the high frequency of data points below the main cluster.

Similarly, the "Normal" algorithm (Figure 4.11) under-predicts $\dot{V}O_2$ for several rehabilitation subjects.

"Rehabilitation" algorithm:

Predicted $\dot{V}O_2$ =

$$19.07 + (A-\bar{A})^2\,(-0.009) + (HR-\overline{HR})^2\,(-0.00008) + (Wt-\overline{Wt})^2\,(0.005) + (T-\bar{T})\,(Wt-\overline{Wt})\,(-0.03) + HR\,(0.07) + (HR-\overline{HR})\,(S-\bar{S})\,(0.07) + (T-\bar{T})^2\,(-0.16) + S\,(4.19) + A\,(0.002) + Wt\,(-0.2) + (T-\bar{T})\,(S-\bar{S})\,(0.075) + T\,(1.31) + (HR-\overline{HR})\,(Wt-\overline{Wt})\,(0.001) + (HR-\overline{HR})\,(T-\bar{T})\,(-0.001) + (A-\bar{A})\,(HR-\overline{HR})\,(-0.0006) + (A-\bar{A})\,(Wt-\overline{Wt})\,(0.002) + (A-\bar{A})\,(T-\bar{T})\,(-0.006) + (Wt-\overline{Wt})\,(S-\bar{S})\,(-0.12).$$

"Normal" algorithm:

Predicted $\dot{V}O_2$ =

$$26.98 + (A-\bar{A})^2\,(0.005) + (HR-\overline{HR})^2\,(-0.0008) + (Wt-\overline{Wt})^2\,(-0.003) + (T-\bar{T})\,(Wt-\overline{Wt})\,(-0.00003) + HR\,(-0.04) + (HR-\overline{HR})\,(S-\bar{S})\,(0.03) + (T-\bar{T})^2\,(-0.13) + S\,(3.17) + A\,(-0.05) + Wt\,(-0.11) + (T-\bar{T})\,(S-\bar{S})\,(-0.00009) + T\,(2.42) + (HR-\overline{HR})\,(Wt-\overline{Wt})\,(0.00000000003) + (HR-\overline{HR})\,(T-\bar{T})\,(0.00000002) + (A-\bar{A})\,(HR-\overline{HR})\,(0.0002) + (A-\bar{A})\,(Wt-\overline{Wt})\,(0.0001) + (A-\bar{A})\,(T-\bar{T})\,(-0.0009) + (Wt-\overline{Wt})\,(S-\bar{S})\,(-0.000007).$$

"All" algorithm:

Predicted $\dot{V}O_2$ =

$$21.18 + (A-\bar{A})^2\,(0.005) + (HR-\overline{HR})^2\,(-0.0005) + (Wt-\overline{Wt})^2\,(0.001) + (T-\bar{T})\,(Wt-\overline{Wt})\,(0.00001) + HR\,(-0.008) + (HR-\overline{HR})\,(S-\bar{S})\,(0.04) + (T-\bar{T})^2\,(-0.12) + S\,(3.61) + A\,(-0.06) + Wt\,(-0.1) + (T-\bar{T})\,(S-\bar{S})\,(0.0001) + T\,(2.22) + (HR-\overline{HR})\,(Wt-\overline{Wt})\,(0.00000000002) + (HR-\overline{HR})\,(T-\bar{T})\,(0.00000002) + (A-\bar{A})\,(HR-\overline{HR})\,(-0.0004) + (A-\bar{A})\,(Wt-\overline{Wt})\,(0.00008) + (A-\bar{A})\,(T-\bar{T})\,(0.002) + (Wt-\overline{Wt})\,(S-\bar{S})\,(-0.000007).$$

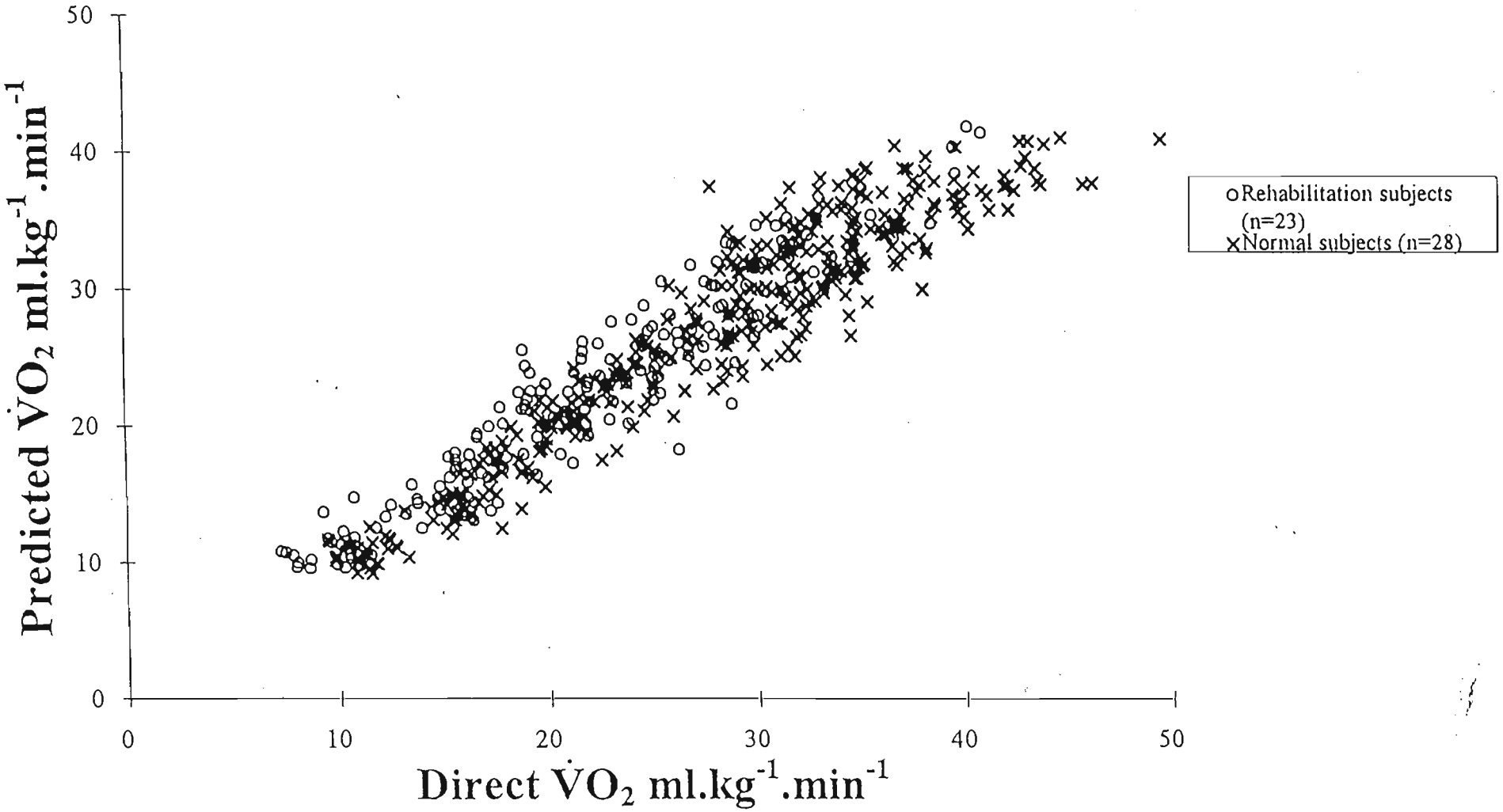


Figure 4.9: Oxygen consumption: predicted versus directly measured for rehabilitation and normal subjects (using the "All" algorithm).

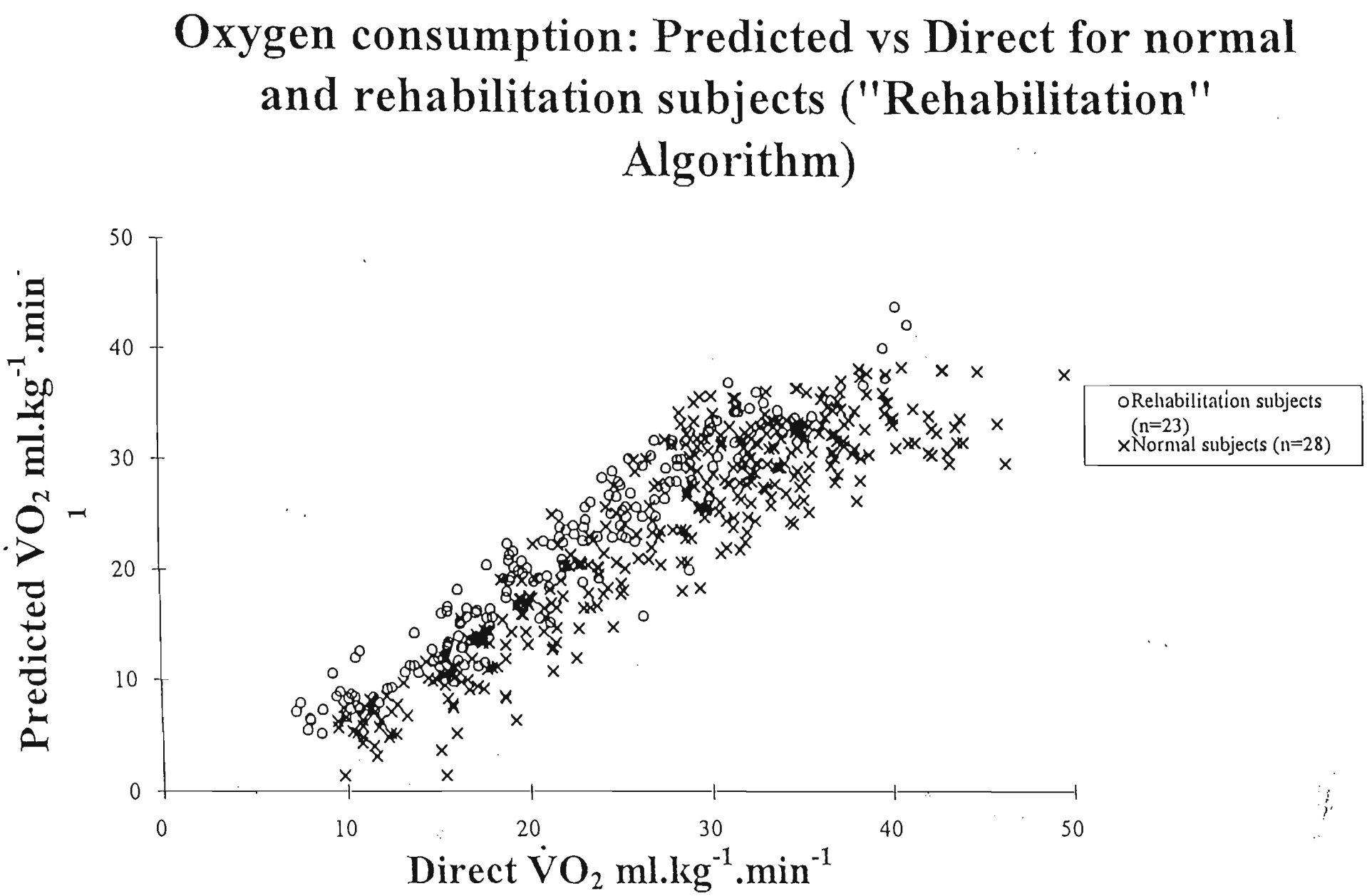


Figure 4.10: Oxygen consumption: predicted versus directly measured for rehabilitation and normal subjects (using the "Rehabilitation" algorithm).

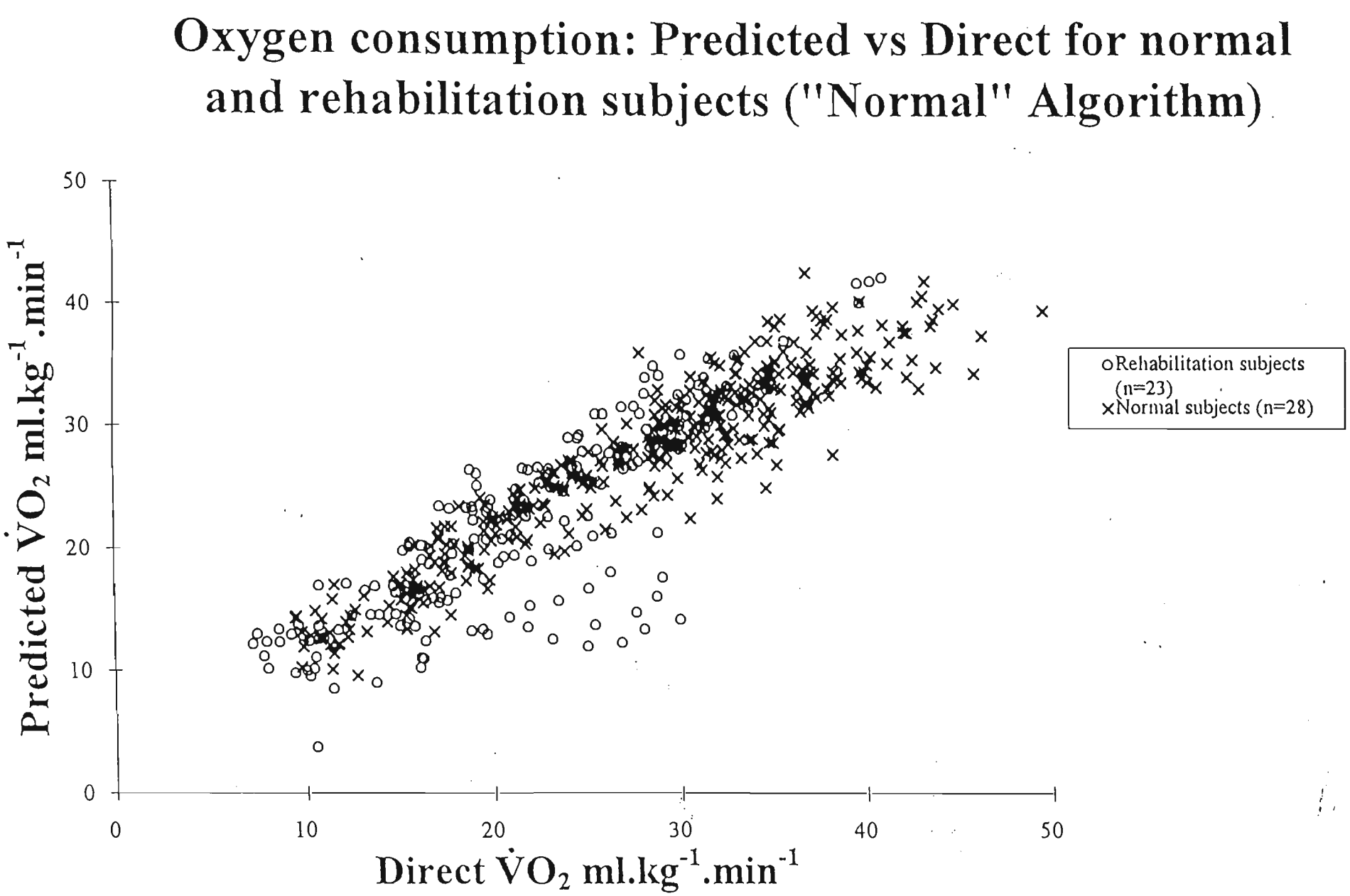


Figure 4.11: Oxygen consumption: predicted versus directly measured for rehabilitation and normal subjects (using the "Normal" algorithm).

4.3.2 Testing the strength of the algorithms

There was a significant main effect for "algorithm" ($p < 0.001$). Tukey post-hoc analysis (Appendix D) located all of the significant differences in "algorithm" to the Rehabilitation algorithm. Table 4.5 shows $\dot{V}O_2$, predicted from the three algorithms, and the directly measured $\dot{V}O_2$; each number represents the mean ± sd for the first six minutes of the test. Of the three algorithms, $\dot{V}O_2$ is 2.0 ± 0.3 $ml.kg^{-1}.min^{-1}$ lower for Rehabilitation than for the other two and the directly measured $\dot{V}O_2$ ($p < 0.001$).

Time	Direct $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)	Rehabilitation $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)	Normal $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)	All $\dot{V}O_2$ ($ml.kg^{-1}.min^{-1}$)
1st Minute	10.7 ± 1.6	9.7 ± 1.8	11.2 ± 1.9	11.3 ± 1.3
2nd Minute	15.8 ± 2.2	13.1 ± 1.8	15.0 ± 1.9	14.9 ± 1.3
3rd Minute	18.2 ± 2.4	16.2 ± 1.9	18.5 ± 1.9	18.2 ± 1.3
4th Minute	21.0 ± 2.1	19.2 ± 2.1	21.7 ± 2.0	21.3 ± 1.3
5th Minute	24.2 ± 2.7	22.1 ± 2.4	24.4 ± 2.1	24.0 ± 1.4
6th Minute	27.6 ± 3.5	26.5 ± 1.6	26.6 ± 2.3	26.5 ± 1.6

Table 4.5: $\dot{V}O_2$ mean values over the first six minutes for the directly measured and predicted Rehabilitation, Normal and All algorithms.

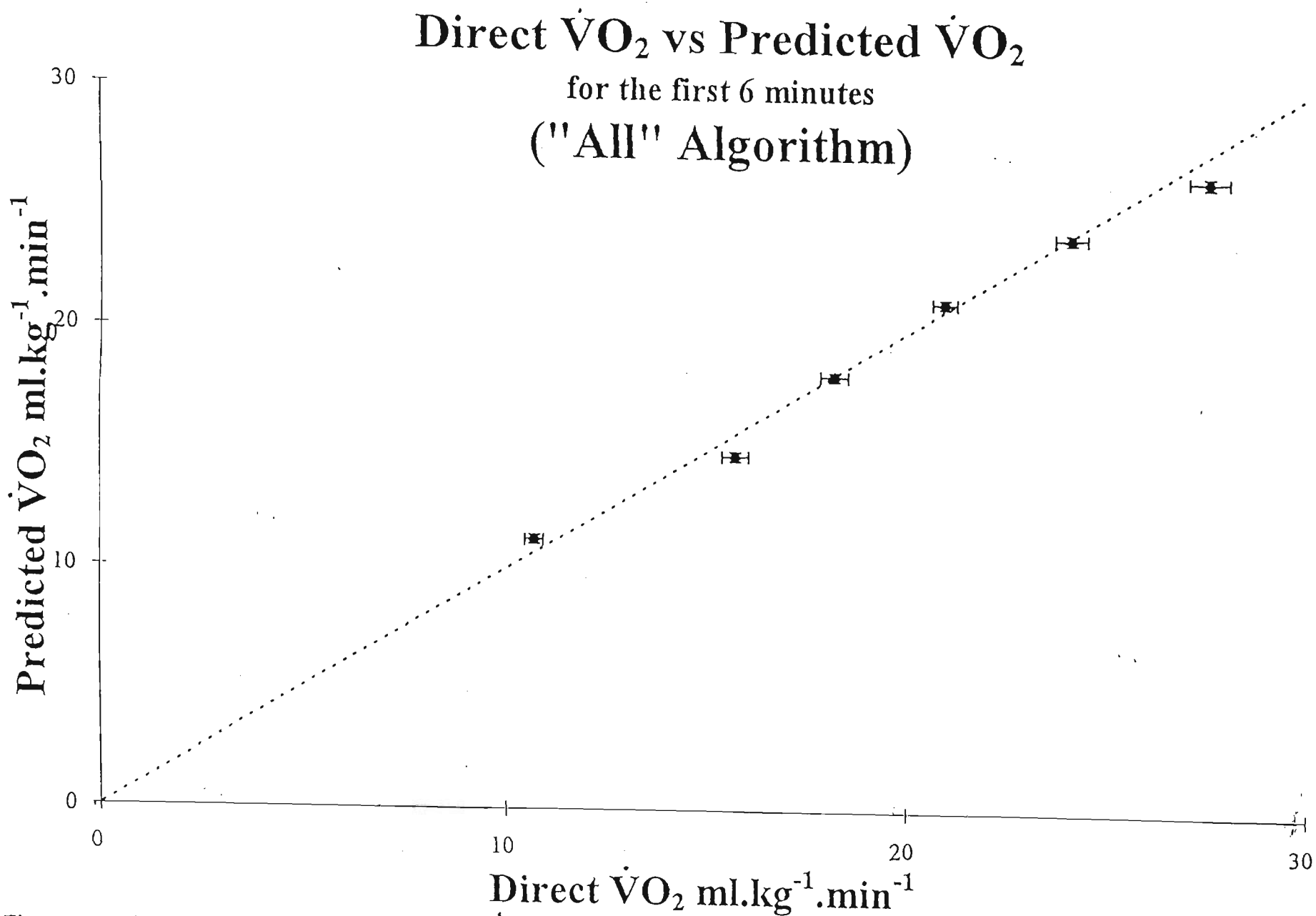


Figure 4.12: Directly measured versus predicted $\dot{V}O_2$ (mean ± sd) for all subjects who completed the first six minutes (using the "All" algorithm)

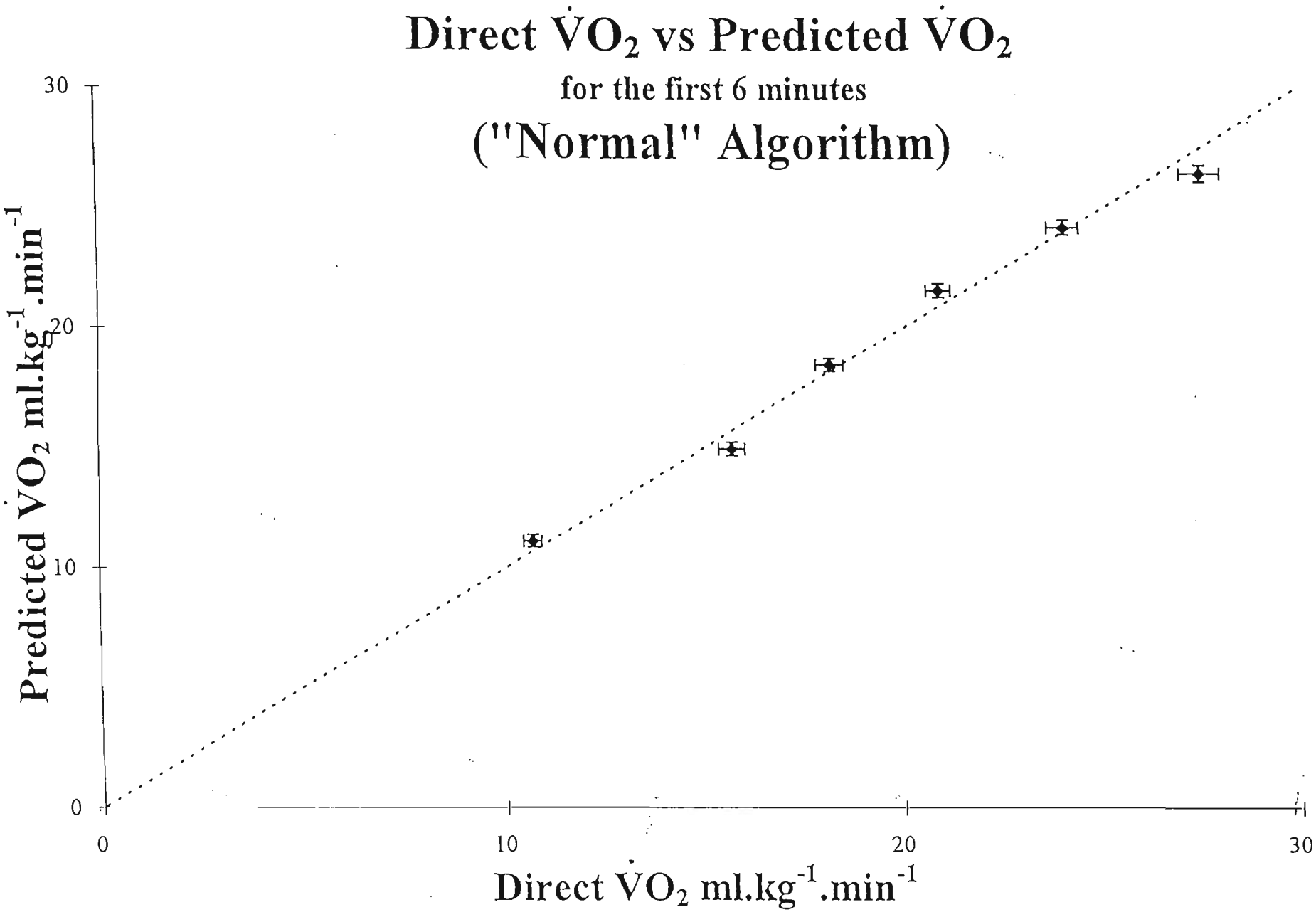


Figure 4.13: Directly measured versus predicted $\dot{V}O_2$ (mean ± sd) for all subjects who completed the first six minutes (using the "Normal" algorithm)

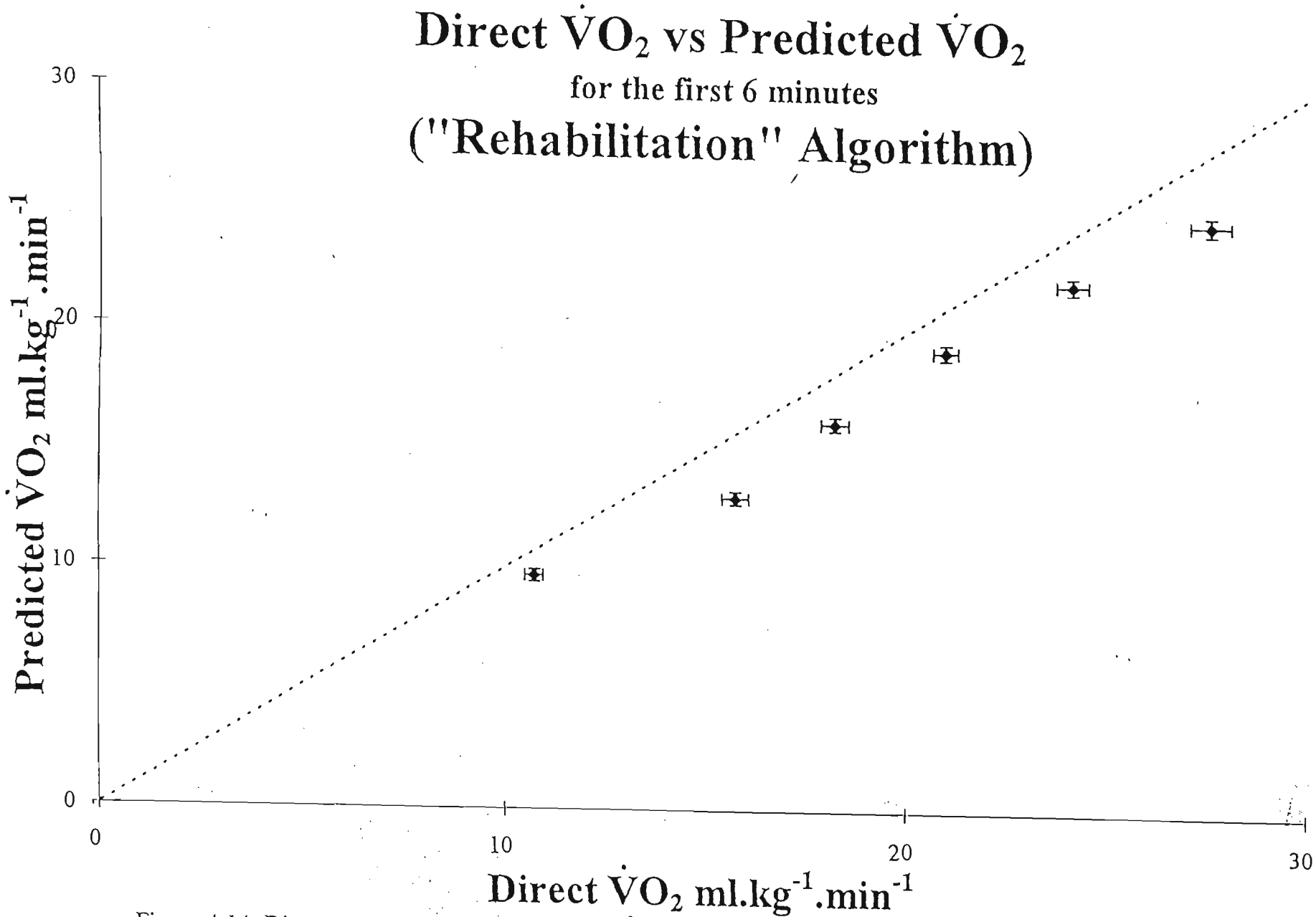


Figure 4.14: Directly measured versus predicted $\dot{V}O_2$ (mean ± sd) for all subjects who completed the first six minutes (using the "Rehabilitation" algorithm)

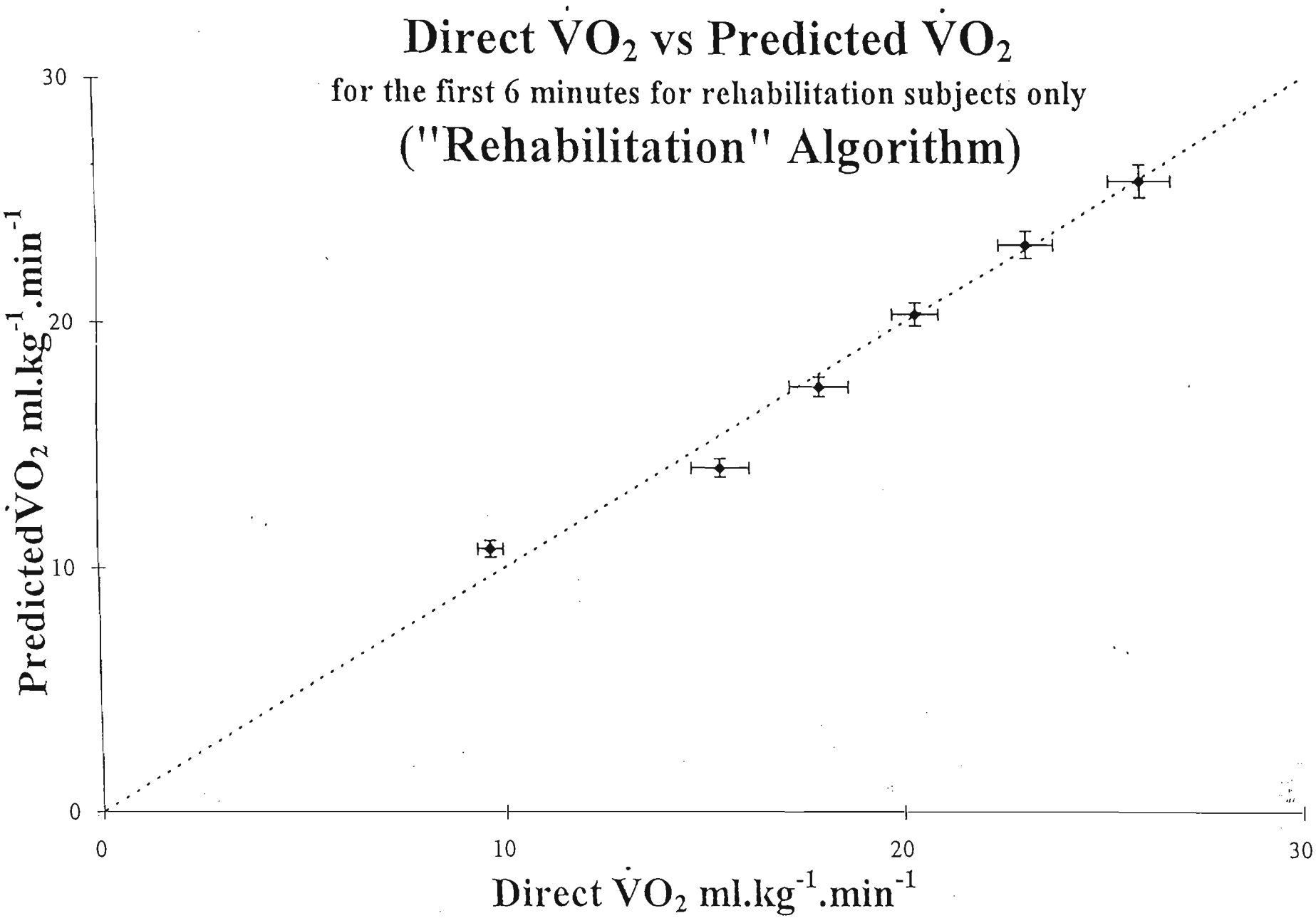


Figure 4.15: Directly measured versus predicted $\dot{V}O_2$ (mean ± sd) for rehabilitation subjects only who completed the first six minutes (using the "Rehabilitation" algorithm)

4.3.3 Maximal Test Estimations

The protocol endeavoured to push the subjects to their maximal oxygen capacity but not all subjects reached this level. The following tables (Table 4.6 and 4.7) show data for normals and rehabilitation subjects respectively which indicate whether maximal or close to maximal levels were achieved. The following tables give an indication that 25% of normal subjects reached a maximal level while 74% of all rehabilitation subjects that completed the protocol reached maximal levels during the test. The indicator that a maximal level had been reached was an RER equal to or greater than 1.1, $\dot{V}O_2$ plateau, a Borg RPE equal to or greater than 18 and a heart rate equal to or greater than the individuals predicted maximum (220-age).

Normals	RER	RER	$\dot{V}O_2$	$\dot{V}O_2$	Borg	Borg	HR	HR
	≥ 1.1	< 1.1	plat	not plat	≥ 18	< 18	≥ 220-age	< 220-age
2nd last min	25%	75%	14%	86%	32%	68%	18%	82%
last min	25%	75%	25%	75%	43%	57%	25%	75%

Table 4.6: Normal subjects (%) indicating whether maximal levels of exercise were attained.

Rehabilitation	RER	RER	$\dot{V}O_2$	$\dot{V}O_2$	Borg	Borg	HR	HR
	≥ 1.1	< 1.1	plat	not plat	≥ 18 pts	< 18	≥ 220-age	< 220-age
2nd last min	74%	26%	13%	87%	43%	57%	9%	91%
last min	74%	26%	35%	65%	70%	30%	26%	74%

Table 4.7: Rehabilitation subjects (%) indicating whether maximal levels of exercise were attained.

Twenty three (six normal and 17 Rehabilitation) subjects reached $\dot{V}O_{2max}$. $\dot{V}O_{2max}$ averaged 30.2 $ml.kg^{-1}.min^{-1}$ when measured directly, compared to 32.7 $ml.kg^{-1}.min^{-1}$ when the "All" algorithm was applied to a predicted peak heart rate of 220-age ($r = 0.81$, $p<0.01$).

4.4 Reliability

Heart rate showed a reliability coefficient of 0.98 with a decrease in heart rate of 4 $b.min^{-1}$ (3%, $p < 0.001$) over 86 observations when the test was repeated in the same subject. While this indicates no significant difference between the two tests for heart rate, Figure 4.15 shows a decrease in heart rate for the second test when compared to the first test. $\dot{V}O_2$ measured over 83 observations showed a correlation coefficient of 0.98 and a 1.4 $ml.kg^{-1}.min^{-1}$ (4.5%, $p < 0.001$) decrease from the first to the second test. Figure 4.16 shows the decrease for $\dot{V}O_2$ between the two tests.

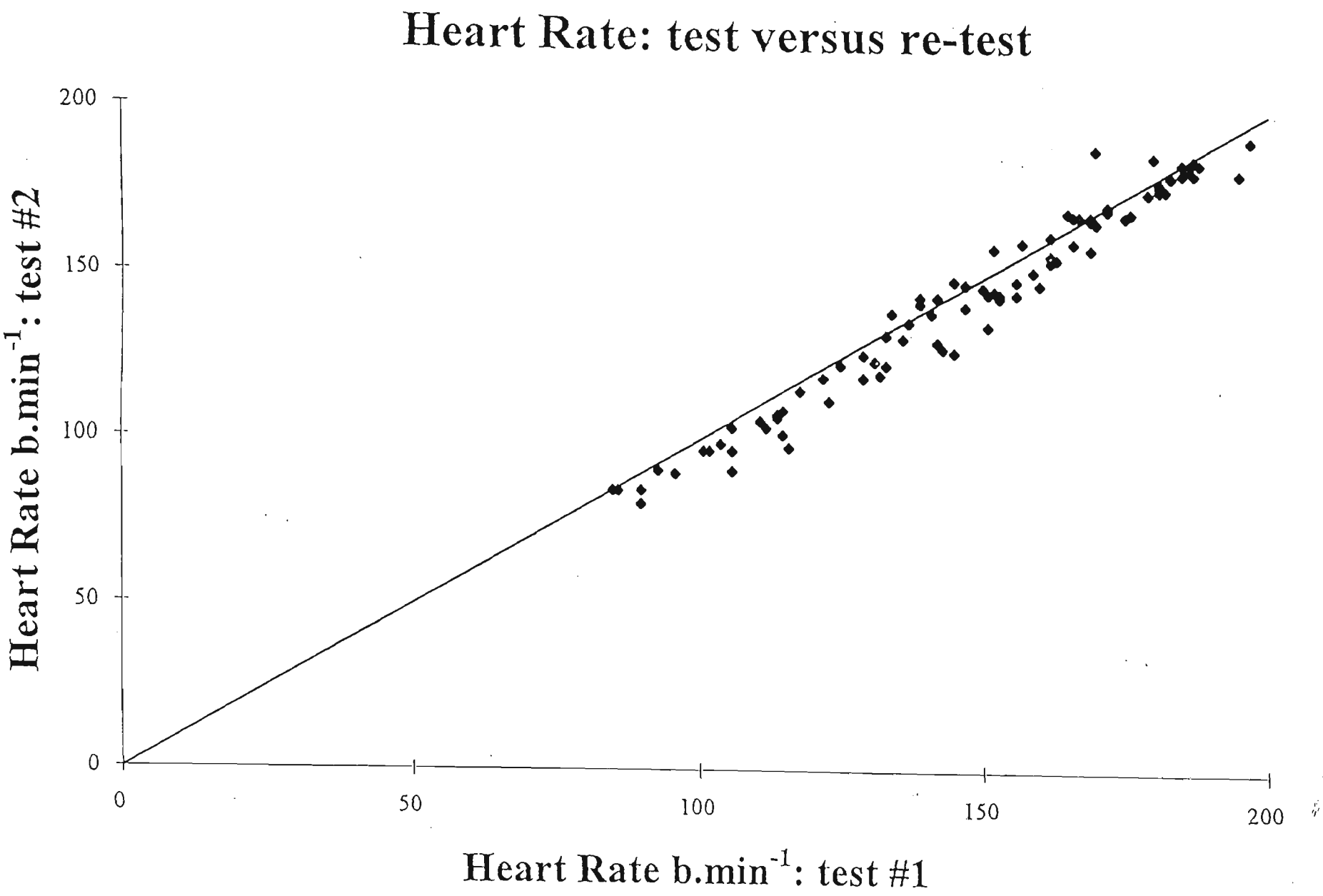


Figure 4.16: Comparison of heart rate ($b.min^{-1}$): test versus re-test

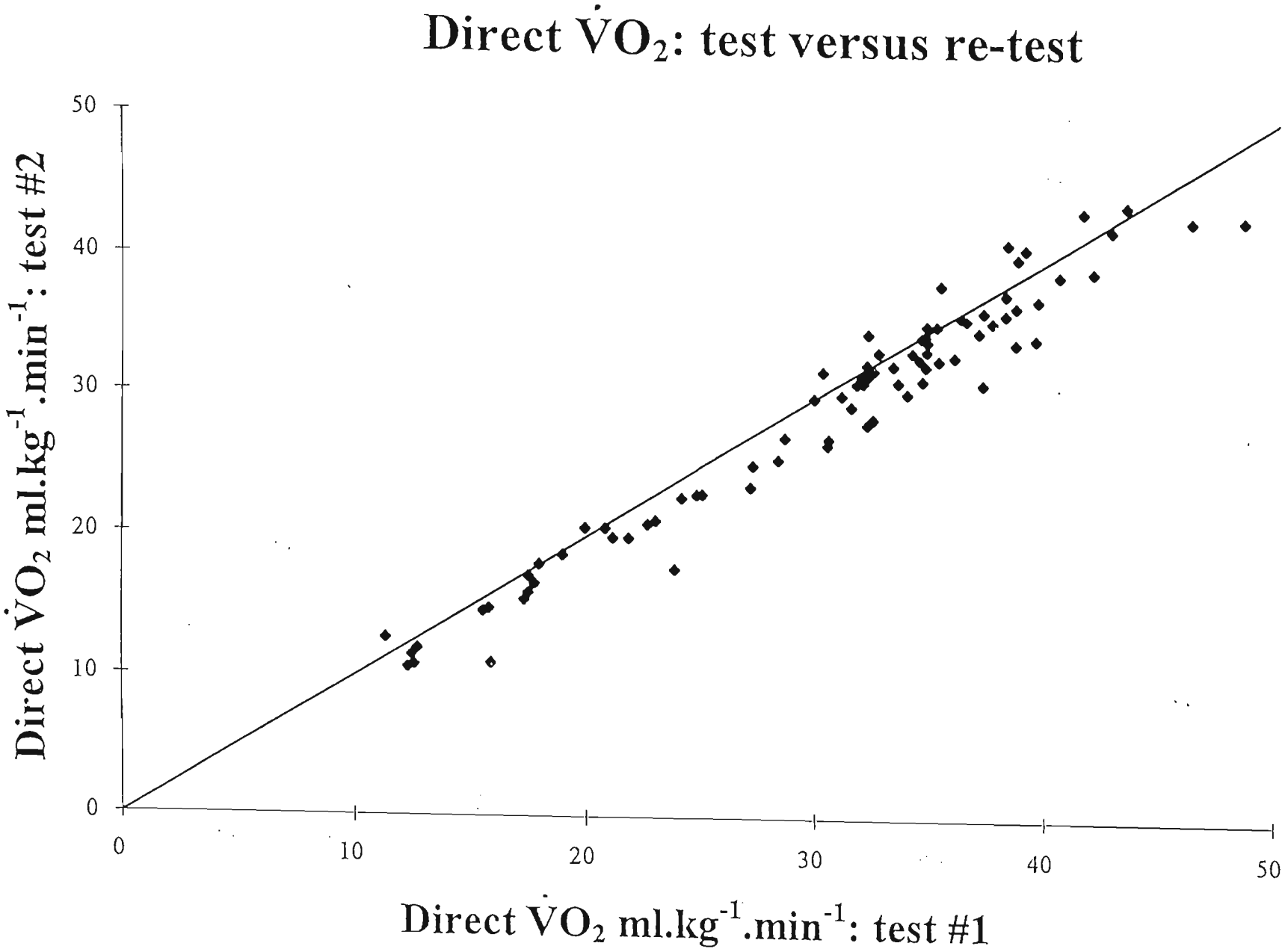


Figure 4.17: Comparison of directly measured $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}): test versus re-test

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This research has provided a protocol for predicting submaximal and maximal oxygen consumption in people undergoing rehabilitation or with low exercise tolerance (LET) that is accurate (r^2 = 0.90-0.94), reliable (r = 0.98), simple (needing only the measurements of heart rate, time, height and weight) and safe (multi-stage, starting at a low intensity, ECG monitoring during the test). LET populations include people undergoing exercise rehabilitation and normal subjects with sedentary lifestyles. The rationale for using step tests in the assessment of aerobic power for people with LET includes the functional appropriateness of the exercise (compared to cycling), safety (compared to treadmill), the ease of administration (compared to treadmill and cycling), the ease of data analysis (computer algorithm) and the negligible cost of administering the protocol (compared to treadmill and cycling).

The strengths of the protocol and the algorithm developed in this research are: (i) the use of statute height to determine step height, which enabled subjects to work at the same relative work load; (ii) about half the volunteers were recruited from the LET population (exercise rehabilitation) for which the protocol is intended; (iii) the prediction of submaximal and maximal $\dot{V}O_2$ doesn't rely solely on the measurement of heart rate but includes other variables including age, sex, weight and time (note:

height is already accounted for in the selection of step height); (iv) there is a high validity of the protocol, as it is one of the few tests that measured $\dot{V}O_2$ directly while stepping; (v) the algorithm provided very accurate submaximal $\dot{V}O_2$ predictions and reasonably accurate predictions of maximal $\dot{V}O_2$; (vi) it is simple to administer, only requiring the measurement of heart rate during the test; (vii) it is safe to administer: most step tests measure heart rate only at the conclusion of the test; in contrast, this protocol measures heart rate (and rhythm) by ECG during the test; (viii) the low step height is much more like stepping on a staircase and therefore is more functional than most other step protocols.

A multi-stage test has several advantages over single-stage tests for Rehabilitation and LET people: (a) the test starts at a safe, low power with a built-in warm-up; (b) enables screening for cardiorespiratory disease thresholds; (c) submaximal as well as $\dot{V}O_{2peak}$ predictions are possible: this is important for the identification of a range of work capacities and activities of daily living (ADL's) that a person can accomplish.

5.2 Step Tests

5.2.1 Harvard and Modified Harvard Step Tests

The Harvard Step Test (HST) (Brouha, 1943) prescribes a step height of 50 cm and a stepping rate of 30 $c.min^{-1}$ for up to 5 minutes. Step tests have generally been modified from the HST because the level of exertion required by the HST is excessive for untrained or older individuals (Francis, 1987). Bonen (1975) questioned the safety of the HST for all populations and its inappropriateness for accurately predicting

cardiorespiratory fitness in non-athletic populations. The HST has been modified due to its high intensity and its lack of suitability for people of small stature (Watkins, 1984). Keen and Sloan (1958) postulated that individuals of shorter stature were disadvantaged by the height of the step used in the HST. However they failed to record any physiological data other than recovery heart rates and excluded those subjects from their results who failed to maintain stepping cadence or stopped the test prematurely. A number of step tests have been designed by modifying one or both of the HST's cadence and step height (Bailey *et al.* 1976; Shapiro *et al.* 1976; Tuxworth and Shahnawaz, 1977). In relation to the latter, most modifications prescribed a lower absolute step height but the step height was not adjusted relative to statute height. As a consequence, these step tests are easier to complete than the HST, but the accuracy of prediction was not necessarily improved.

A common criticism of many step tests has been that the test cohort was inappropriate to the target population for which the test was subsequently administered. For the most part they were developed using healthy, young subjects (Brouha, 1943; Howe *et al.*, 1973; Johnson and Siegel, 1981; Keen and Sloan, 1958; Keren *et al.*, 1980; Meyers, 1969; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Witten, 1973). In contrast Bailey *et al.* (1976) used a cohort with a mean age of 35 ± 15 years (mean ± sd; range 15 to 70 years) when they developed a step test intended for the Canadian public. In this thesis, the mean age of the subjects was 35 ± 9 years (range 18 to 61 years). It should be noted that beyond the age of twenty there is a gradual decline in maximal oxygen uptake with increasing age, with fluctuations in inter-individual differences (Åstrand and Rodahl, 1986). Modified HST's are designed to give a prediction of

maximal capacity from a submaximal test but Bonen (1975) claimed that for some individuals, modified HST's are maximal effort tests.

Cooke and Holt (1974) categorised subjects according to their leg length:body weight ratios. They found that the higher this ratio, the higher the fitness index as calculated using the HST categories. The present results are consistent with this: the rehabilitation subjects averaged a lower leg length:body weight ratio than the normal group, and exercised to a lower $\dot{V}O_{2peak}$ and time to fatigue.

5.2.2 Step Tests which Account for Height or Leg Length

In this research, step height was adjusted according to statute height. This study used statute height rather than leg length or femur length to determine step height. Although this is less than perfect ($r = 0.91$, Figure 4.1), the error in measuring leg length or femur length (due to the difficulty in locating anatomical landmarks) can be assumed to be greater than that of statute height. Since this test will be used in the rehabilitation community it is felt that statute height is an easier and simpler measurement. The ratio was adapted from that used by Francis *et al.* (1987, 1988, 1989, 1991, 1992), to make it suitable for rehabilitation and LET populations. The height of a normal stair is approximately 16 cm. In a pilot study, it was found that this height (ie 16 cm) was too low to reach $\dot{V}O_{2peak}$, even for LET people. In the present study, the step height averaged 21.5 ± 1.2 cm; this contrasts with an average height of 31.2 cm in the work by Francis and Culpepper (1989) and an absolute height of 50 cm for the HST.

The problems (with accuracy and validity) of using an absolute step height in a step test to predict $\dot{V}O_{2max}$, rather than a height determined from body dimensions, were addressed using a thoughtful mathematical approach by Francis *et al.* (1987, 1988, 1989, 1991,1992). The ratio of leg length to statute height (Anderson and Green, 1948; Anderson *et al.*, 1978) was used by Culpepper and Francis (1987) to estimate femur length which was used the to determine their ideal step height (for healthy subjects) as the ratio H_{step} = 0.189 x statute height. Pilot work for this thesis revealed that this step height : body height ratio was too severe for the rehabilitation cohort, both from the point of view of exercise intensity and the threshold of low back pain. Using a similar approach to Francis *et al* (1987, 1988, 1989, 1991,1992), the step height to statute height ratio was reduced to H_{step} = 0.125 x height. As a result, the rehabilitation subjects were able to exercise for an average test time of 7.7 ± 2.7 min (instead of less than two minutes for H_{step} = 0.189 x height), compared to 13.0 ± 3.9 min for the normal subjects. Forty eight percent of normal subjects exercised to the end of the prescribed test (16 minutes), while none of rehabilitation subjects completed the 16 minutes. Both groups of subjects were able to maintain cadence and full knee extension until a peak level was attained.

In contrast to these studies, other variable-height step tests were devised for the purpose of providing multi-stage protocols, rather than to prescribe the same relative work load for individuals of different height. For example Elbel and Green (1946) devised a multi-stage protocol using a varying step height moving from 30 cm to 50 cm in 5 cm increments. Ariel (1969) examined the degree of flexion in the knee and how it relates to stepping performance in the HST. He found that scores for the HST test were positively correlated with the height of the subject. Nagle *et al.* (1965)

developed an incremental step test using a step ergometer that increased height at a rate of 2 cm every second minute. They measured $\dot{V}O_2$ directly by collection of expired gas in Douglas bags during the last 60 s of each stage. However for the same reason as given above, this design could also be criticised in that scores for each absolute step height were not adjusted for people with different leg lengths. The present study found an average $\dot{V}O_2$ of 23.9 $ml.kg^{-1}.min^{-1}$ at a cadence of 30 $c.min^{-1}$ and an average step height of 21.5 cm, compared to Nagle *et al.* (1965) who reported a $\dot{V}O_2$ of 24.1 $ml.kg^{-1}.min^{-1}$ at 30 $c.min^{-1}$ at an absolute step height of 20 cm. These results may be partly attributed to the similar age (34 years) and weight (71 kg) profiles of their subjects with those in this study; unfortunately they did not report their subjects' heights.

Comparisons between the present study and that of the series by Francis *et al.* (1987, 1988, 1989, 1991, 1992) are limited to the comparisons of adjusting the step height to account for body dimensions. The input data for their predictions of $\dot{V}O_{2max}$ is different. They used recovery heart rates and correlated these with a treadmill-determined $\dot{V}O_{2max}$ to develop a single-stage submaximal stepping protocol to predict $\dot{V}O_{2max}$. By using $\dot{V}O_{2max}$ measured on a treadmill, it is not possible to predict submaximal $\dot{V}O_2$'s on a step bench, which was a major focus of the current research. Furthermore, validity was improved by direct measurement of $\dot{V}O_2$ while stepping, rather than extrapolating from treadmill data. In the present study, continuous measurement of heart rate was used, rather than recovery heart rates as used by most previous researchers (Francis and Brasher, 1992; McArdle *et al.*, 1972; Miyamura *et al.*, 1975). This enables continues monitoring of subjects, thereby increasing both the safety and validity of the test.

It was important for this research to prescribe an optimum step height, relative to statute height, for LET and rehabilitation subjects. This height needed to be low enough for these people to safely engage in the exercise test (ie lower than H_{step} = 0.189 x statute height), but high enough to physiologically challenge these people (ie higher than H_{step} = 0.100 x statute height, as was trialed in the pilot work). A small number of subjects in this thesis reported the onset of pain or tiredness in their working leg muscles well before reaching $\dot{V}O_{2max}$. However, the main application of the test will be a six minute submaximal test (see Section 5.4.2) and so it is expected that the onset of pain and muscle fatigue will not be significant factors in the prediction of $\dot{V}O_2$, particularly submaximal $\dot{V}O_2$. Cox *et al.* (1992) and Weller *et al.* (1992) reported subjects who completed a maximal effort step test experienced muscle fatigue, thereby limiting their performances and causing post-exercise muscle soreness. Datta *et al.* (1974) and Culpepper and Francis (1987) argued that stepping exercise which causes muscle fatigue will lead to poor technique, physiological inefficiency and unreliable prediction of $\dot{V}O_{2max}$. Steps of above 40.6 cm (16 in) were found to induce early leg fatigue in heavy individuals and those of short stature (Francis and Culpepper, 1989). Failure to maintain correct form has previously been described by investigators who questioned the validity of the HST (Bandyopadhyay and Chattopadhyay, 1981; Datta *et al.*, 1974; Elbel and Green, 1946).

5.2.3 Multi- versus Single-Stage Step Tests

Apart from prescribing step height, cadence and duration, stepping protocols may be designed as single- or multi-stage. Single-stage tests require the subject to step at a

constant intensity (cadence and height, eg. HST, Brouha, 1943). Since the HST, many investigators have used a single-stage protocol (Francis *et al.*, 1987, 1988, 1989, 1991, 1992; McArdle *et al.*, 1972; Shapiro *et al.*, 1976; Tuxworth and Shahnawaz, 1977). Most used recovery heart rates to predict $\dot{V}O_{2max}$, based on the correlation between recovery heart rates and direct $\dot{V}O_{2max}$, determined on a bicycle ergometer or treadmill.

Multi-stage protocols prescribe variations in step height (Nagle *et al.*, 1971), step cadence (Howe *et al.*, 1973; Keren *et al.*, 1980) or a combination of the two variables (Kurucz *et al.*, 1969; Witten, 1973). There are some advantages of multi- over single-stage tests. The former incorporate a warm-up (Nagle *et al.*, 1971) which at the same time, familiarises the subjects with the exercise task (Fitchett, 1985; Francis and Brasher, 1992). This may help to blunt any anticipatory rise in heart rate which is common in the first couple of minutes of many high-intensity tests. In the present study, the increase in cadence enabled measurement of submaximal exercise capacity and heart rates, and the prediction of submaximal $\dot{V}O_2$, which are all important for rehabilitation subjects. By starting at a low level of 14 cycles per minute, 96% of rehabilitation subjects exercised for at least three minutes. Of those rehabilitation subjects who failed to complete six minutes, all stopped due to pain, rather than muscle fatigue.

Another advantage of multi-stage protocols is that they enable safe, symptom-limited testing. Alternatively, they can be used clinically to provoke symptoms. They are used in the detection of threshold markers of cardiovascular disease (CVD), such as ST-segment changes on the ECG or the onset of ischaemic pain (Hampton, 1994;

Hampton, 1993; Schamroth, 1993). It is anticipated that not all facilities that will use this test will be equipped with ECG's (and/or staff trained in ECG interpretation). Nevertheless, the protocol requires the measurement of heart rate **during** the test (by a heart rate monitor or ECG), which should improve the safety over protocols that measure heart rate only at the end of the test.

Another attraction of using multi-stage protocols is that $\dot{V}O_{2max}$ may be extrapolated from submaximal data. $\dot{V}O_{2max}$ can also be predicted for single-stage tests (see above), but generally rely on a single measurement, whereas for multi-stage, $\dot{V}O_{2peak}$ is extrapolated from multiple discrete data points, usually using linear regression. In this way, if there is a data point that obviously is incongruent with the others (eg error in heart rate measurement), it may be discarded in the analysis, provided there is good reason for doing so.

5.3 Development of the Algorithms

5.3.1 Accuracy

The independent variables that increased the strength of prediction were age, sex, weight, heart rate and time. Borg RPE's and sum of eight skinfolds did not add strength to the prediction (both reduced r^2) and were discarded, which was pleasing from the point of view of the algorithms' usefulness to the exercise rehabilitation industry. Borg RPE's are subjective and skinfold measurements have a high intra- and inter-experimenter error (Lohman *et al.*, 1988). When administering this test to LET people, Borg RPE's will be monitored for safety, but will not be used to predict $\dot{V}O_2$,

and skinfolds will not need to be taken, thereby alleviating some of the anxiety and/or embarrassment of participants.

Three algorithms were produced: "Rehabilitation", "Normal" and "All", and these were compared to oxygen consumption measured directly ("Real"). There were no significant differences between "Normal", "All" and "Real" (Table 4.5; Figures 4.13 and 4.12), but all three were significantly higher than "Rehabilitation" (Figure 4.14), when all of the subjects (ie normal and rehabilitation) were included. The "Rehabilitation" algorithm was satisfactory when the normal subjects were excluded (Fig 4.15). The intended use of the protocol is for people who are undergoing exercise rehabilitation, some of whom will have nearly normal exercise capacities (compared to sedentary individuals), while others will be disabled. Therefore it is recommended that the "All" algorithm be used, as this will obviate the necessity for selecting an algorithm, based on arbitrary criteria concerning the person's health status. The "All" algorithm (Figures 4.9, 4.12) indicates a tight grouping for all subjects in comparing predicted with direct $\dot{V}O_2$. The "Rehabilitation" algorithm (Figure 4.10) underestimated $\dot{V}O_2$ for several normal subjects and the "Normal" algorithm (Figure 4.11) underestimated $\dot{V}O_2$ for several rehabilitation subjects. This lends support for the use of a single algorithm for the prediction of $\dot{V}O_2$ in both rehabilitation and normal subjects, the latter when exercising at low intensity.

5.3.2 Reliability and Validity

The test-retest reliability was high for directly measured $\dot{V}O_2$ ($r = 0.98$) and heart rate ($r = 0.98$). These test-retest correlations compare favourably with other $\dot{V}O_2$

prediction tests (Leger and Gadoury, 1989; McArdle *et al.*, 1972). $\dot{V}O_2$ and heart rate were slightly lower on the retest by an average of 1.4 $ml.kg^{-1}.min^{-1}$ (4.5%) and 4 $b.min^{-1}$ (2.9%), respectively (Figures 4.11 and 4.12). This was probably due to familiarisation with equipment and the protocol, which may have increased physiological efficiency on the second test. These results show that ideally a familiarisation trial should precede every exercise assessment. However, in its application in the rehabilitation industry, it is unlikely that provision will be made for a familiarisation test before each assessment, and furthermore, the protocol will rarely be used in a test-retest situation. It is expected that the test will mainly be used to assess an individual's current functional capacity.

Correlation coefficients between predicted $\dot{V}O_{2max}$ derived from submaximal stepping exercise and other measurements, have been reported to range between 0.72 (Bailey *et al.*, 1976) and 0.94 (Kurucz *et al.*, 1969). Bailey *et al.* (1976) developed a home fitness step test which they claimed to be suitable for testing the broad population of Canada. However, they only compared submaximal stepping with a submaximal bicycle ergometer protocol, therefore attempting to validate a prediction against a prediction. In the present study, the correlation coefficients between predicted and direct $\dot{V}O_2$ ranged from 0.94 to 0.97 (ie r^2 = 0.90 to 0.94). The higher correlation coefficients, and therefore the higher validity, may be partly attributed to the direct measurement of $\dot{V}O_2$ during stepping exercise, whereas most other published protocols were based on direct measurement of $\dot{V}O_2$ during cycling or treadmill exercise.

5.4 Implementation of the Step Test

5.4.1 Target Population

This test is aimed at people undergoing physical and psychological rehabilitation, the elderly and LET individuals. The rationales for using a step height that was substantially lower than previously published protocols was that (i) it was only slightly higher than a normal (staircase) step and (ii) the rehabilitation group, including those with low back pain, were able to manage the prescribed exercise intensities with a low incidence of pain or discomfort.

The predictions of $\dot{V}O_2$ reached a plateau at about 40 $ml.kg^{-1}.min^{-1}$ (Figure 4.8). Since many healthy individuals record $\dot{V}O_{2peak}$'s in excess of this, the test is only recommended for those subjects who fit into the rehabilitation / LET categories. This was confirmed by the fact that no subjects reached a $\dot{V}O_{2peak}$ (by direct measurement) in excess of 50 $ml.kg^{-1}min^{-1}$. Therefore the protocol prescribed exercise intensities that are too low for athletic populations.

5.4.2 The Six Minute Submaximal Step Test

Application of the step test for the field of exrcise rehabilitation resulted in the development of a six minute submaximal protocol. This test follows the same protocol as the maximal test, increasing cadence by 4 $c.min^{-1}$ from 14 $c.min^{-1}$ until the maximal cadence (34 $c.min^{-1}$) is reached, at which time the test was terminated (Appendix E).

The termination of the test after six minutes avoids safety problems associated with rehabilitation subjects exercising with added weight or to maximal effort.

A six minute multi-stage test has some advantages over three minute single-stage tests. Firstly, three minutes is considered too short for a multi-stage protocol, considering that the first minute of heart rates may be unreliable (physiologically) due to anxiety, while a single-stage test generally relies on recovery heart rates. Secondly, a safer, more accurate predictive test is provided. Thirdly, with discreet data points collected during the testing period, $\dot{V}O_{2max}$ may be predicted using linear extrapolation from the accrued submaximal data.

Anxiety can elevate the pre-exercise heart rate and also heart rates during competition (Hanson, 1966). Omission of first minute heart rates decreases the effects of anxiety or anticipation on the subject's predicted results. The submaximal protocol relies on the heart rate data being recorded from the second minute, as heart rate then becomes physiological (Watkins, 1984).

5.4.3 Extrapolation to $\dot{V}O_{2max}$

The prediction of $\dot{V}O_{2max}$ from the submaximal data relies on the assumption that maximal heart rate may be reliably predicted as 220 - age (Asmussen and Molbech, 1959; Kasch, 1984; Legge and Banister, 1986; Weller *et al.*, 1992). While some researchers use it, some question its accuracy (Buono *et al.*, 1991). $\dot{V}O_{2max}$ was estimated by linear extrapolation of the submaximal data for heart rate and predicted $\dot{V}O_2$ (Appendix F) to the predicted maximal heart rate. When those subjects who

reached $\dot{V}O_{2max}$ during the step protocol were compared to their predicted $\dot{V}O_{2max}$, there was a statistically significant correlation (r = 0.81) between the predicted $\dot{V}O_{2max}$ and actual directly measured $\dot{V}O_{2max}$.

5.4.4 Drugs that Influence Heart Rate: Effects on Test Data and Predicted $\dot{V}O_2$

Drugs that alter heart rate often cause errors in the prediction of $\dot{V}O_2$. For example, beta-blockers have the effect of decreasing heart rate and heart function (Tesch, 1985). Therefore any predictive test of $\dot{V}O_2$ that relies heavily on the measurement of exercise heart rate will be flawed. The present study developed algorithms which rely on the variables of test duration, sex, weight, age and heart rate to predict submaximal and maximal $\dot{V}O_2$. The table below (Table 5.1) is an example of heart rates and predicted $\dot{V}O_2$ responses for two identical 70 kg males (25 years), comparing the subjects with and without the use of beta-blockers (using the "All" algorithm). The changing variables in this test are time and heart rate.

Test Duration (min)	Normal: Heart rate ($b.min^{-1}$.)	Normal: Submaximal $\dot{V}O_2$'s ($ml.kg^{-1}.min^{-1}$.)	Beta-Blockers: Heart rate ($b.min^{-1}$.)	Beta-Blockers: Submaximal $\dot{V}O_2$'s ($ml.kg^{-1}.min^{-1}$.)
2	106	15.7	76	16.1
3	114	19.3	84	19.8
4	126	22.7	98	22.9
5	138	25.8	108	25.8
6	156	29.0	126	28.2

Table 5.1: Hypothetical comparison using the "All" algorithm of heart rate and predicted submaximal $\dot{V}O_2$ in a 70 kg male using beta-blockers to an "identical" individual not on beta-blockers

Predicted $\dot{V}O_{2max}$, determined by the six minute extrapolation method (Appendix E) was 40.0 $ml.kg^{-1}.min^{-1}$ for no drug and 45.5 $ml.kg^{-1}.min^{-1}$ if the subject was on beta-blockers. However, when $\dot{V}O_{2max}$ was predicted using the Åstrand-Ryhming nomogram for the same two peaks in heart rate (ie 156 versus 126, see Table 5.1, above), the difference in $\dot{V}O_{2max}$ was much greater (40.0 $ml.kg^{-1}.min^{-1}$ to 57.1 $ml.kg^{-1}.min^{-1}$), although it must be recognised that this is a different protocol. Nevertheless, this illustrates that the impact of drugs which influence heart rate in the current protocol are low for submaximal predictions, and less than for the Åstrand-Ryhming protocol for the prediction of $\dot{V}O_{2max}$.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

6.1 Conclusions

This research has developed an accurate and safe submaximal step test for individuals undergoing exercise rehabilitation. The features of this study were: i) the development of a step test that accounts for statute height by varying the step height in accordance to a formula ($H_{step} = H_{subject} \times 0.125$); ii) the protocol uses functional exercise (stepping) to predict submaximal and maximal $\dot{V}O_2$; iii) the sample group included a rehabilitation and LET group, for which the test was specifically developed; iv) the development of a six minute submaximal protocol which can be used to predict submaximal $\dot{V}O_2$ accurately ($r^2 = 0.90$) and vi) creation of a reliable testing protocol.

6.2 Recommendations For Further Research

The present study indicates a strong prediction of $\dot{V}O_2$, for both submaximal and maximal exercise. It is recommended that testing both sexes across a broad age range will strengthen the algorithm for use by a wide population encompassing rehabilitation, LET and normal subjects. The algorithms would be adapted from these tests and new means incorporated into the equations.

For testing on normal subjects it is recommended that the step height:body height ratios of Culpepper and Francis (1987) be used to develop algorithms using the approach described in this thesis: multi-stage, based on direct measurement of $\dot{V}O_2$.

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Appendix A
(Comparison of different sub-maximal and maximal tests)

TEST	Accuracy	Validity	Reliability	Direct?	Quantalitive?	Maximal or sub-maximal	Warm-up included in protocol	Local muscle fatigue	Skill required to perform test	Motivation required by subject to do test
Incremental treadmill test: direct VO_2 max 'gold standard'	+++	+++	+++	Y	Y	M, SM	+++	+++	++	+++
Astrand-Rhyming, PWC and Tri-level	-	++	-	N	Y	SM	+	- -	-	++
Step tests	+	-	++	N	N	SM	-	- - -	+	-
5 and 12 minute runs	++	+	+	N	N	M	- - -	+++	++	- -
Shuttle run test	++	+++	++	N	Y	M	+++	+++	+	+++

Appendix B
(Informed consent information)

VICTORIA UNIVERSITY OF TECHNOLOGY
Exercise Test Appointment Sheet

NAME: .....

DATE OF APPOINTMENT: .....

TIME OF APPOINTMENT: .....

ADDRESS: Room L305
Department of Physical Education and Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

PHONE NO: (03) 9688 4421 (Dr. Steve Selig)

FAX: (03) 9688 4891

INSTRUCTIONS:

1. Do not exercise on day to test.
2. If exercising on day before test then make it light exercise.
3. Eat a light meal 2-3 hours prior to the test, or as directed. Avoid coffee, tea, alcohol and non-prescription drugs for three hours prior to the test.
4. Bring running shoes and shorts, or tracksuit.
5. Females wear bikini top or sports bra. Wear a T-shirt over the top.
6. Change and shower facilities are available (bring towel.)
7. Return any other papers that have been sent to you, and ensure that you have supplied the information where indicated and signed the forms.
8. Medical Supervision: if you are **under 35 years**, then you will not normally need medical supervision; however we will arrange for medical supervision if you prefer or if your risk factors or medical history indicate the need for supevision. If you are **over 35 years**, you will require medical supervision unless your doctor is willing to give consent to you exercising at maximal intensity without medical supervision.
8. Car parking: .....
9. Other instructions: .....

Victoria University of Technology
Ballarat Road
Footscray
PO Box 14428
MMC
Melbourne
Victoria 3000
Australia

Telephone
(03) 688 4000
Facsimile
(03) 689 4069

Footscray Campus
Department of
Physical Education
and Recreation
Telephone
(03) 688 4470
(03) 688 4473
Facsimile
(03) 688 4891

VICTORIA UNIVERSITY OF TECHNOLOGY

STANDARD CONSENT FORM FOR SUBJECTS INVOLVED IN EXPERIMENTS

VICTORIA UNIVERSITY OF TECHNOLOGY

CERTIFICATION BY SUBJECT

I,
of
certify that I have the legal ability to give valid consent and that I am voluntarily giving my consent to participate in the experiment entitled :

Development of a protocol for the prediction of the aerobic power, using a sub-maximal graded step test.

being conducted at Victoria University of Technology by :

I certify that the objectives of the experiment, together with any risks to me associated with the procedures listed hereunder to be carried out in the experiment, have been fully explained to me by :

Dr.Steve Selig

and that I freely consent to participation involving the use on me of these procedures.

Procedures
Risk Factor Assessment
Exercise test: incremental test up to VO_2max
Venepuncture
Monitoring of ECG, blood pressure, heart rate and rhythm, perceived exertion, lung ventilation before, during and after exercise test.

I certify that I have had the opportunity to have my questions answered and that I understand that I can withdraw from the experiment at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the confidentiality of the information I provide will be safeguarded.

Signed : .....)
)
Witness other than the experimenter :) Date : .....
)
.....)

INFORMATION SHEET for able-bodied subjects participating in a research project entitled

"Development of a protocol for the prediction of aerobic power, using a sub-maximal graded step test".

This research has been commissioned by the Commonwealth Rehabilitation Service to devise an exercise test which will be subsequently used by the CRS to estimate a client's aerobic fitness (indexed by maximal oxygen uptake, VO_2max). The research project will require subjects to perform a graded step test (using Reebok steps) beginning at a moderate level of intensity and progressing up to their personal maximal exertion level which will they need to sustain for a period of approx. 2 minutes. From the results of the research, we aim to design a sub-maximal version of the test which we hope will be widely used by CRS as a simple, safe and effective method of assessing VO_2max and, in this way, measuring the progress that clients are making in their fitness programs.

TEST PROTOCOL

The test will begin at an easy intensity and then the intensity will increase gradually according to the following plan:

** *Time (minutes)*	*Step Height (cm)*	*Stepping frequency = the number of the following cycles per minute:* UP-UP-DOWN-DOWN
0 to 2	≡ 0.189 x height of the subject	18
2 to 4	≡ 0.189 x height of the subject	22
4 to 6	≡ 0.189 x height of the subject	26
6 to 8	≡ 0.189 x height of the subject	30
8 to 10	≡ 0.189 x height of the subject	34
10 to 12	≡ 0.189 x height of the subject	38
12 to 14	≡ 0.189 x height of the subject	42 (if required)

** The duration of the test will vary between each individual; the fitter you are, the longer the test will last and vice versa. We may stop the test at any time if signs or symptoms occur that indicate that it is wise to stop; alternatively you may stop whenever you wish if you feel tired, uncomfortable or distressed. We want you to exercise as long as you are able, with the ideal situation (from the point of view of the research) being that you reach your personal maximal aerobic power (VO_2max) during the last two minutes of the test. However, we will stop the test when you reach *any one of the following criteria* for stopping:

(i) you wish to stop

(ii) you experience chest pain (typical of angina), severe shortness of breath or any other pain related to, or caused by the exercise.

(iii) you wish to continue but there are abnormal changes to the ECG or blood pressure responses or other signs of cardiorespiratory distress are evident (eg facial pallor)

(iv) you perceive that you are working maximally

(v) your respiratory exchange ratio has reached 1.10

(vi) you reach VO_2max (indicated by no further increases in VO_2 for two successive workloads).

OTHER PROCEDURES

For safety, your blood pressure will be measured prior to, and at the end of the test and your ECG (for heart rate and heart rhythm) and breathing will be monitored throughout. In order to monitor breathing, you will need to wear a valve in your mouth and have a nose clip fitted. This normally doesn't cause any distress, but if it is does in your case, then you need to tell us immediately. You will also be asked frequently during the test about how you are feeling *in general* (breathing, legs, back, etc.) and it is important that you respond accurately to this. Hand signals will be standardised to help communicate during the exercise.

BLOOD SAMPLING

Prior to the test, some subjects will have a catheter inserted into a superficial vein in the forearm. Once the catheter is in place, it is a simple and painless procedure to draw blood samples. This will allow us to measure some of the changes in the blood that happen in response to the exercise. *This does / does not apply to you* (delete the inapplicable words). If you are going to have a catheter inserted, then there is a separate informed consent form (attached) that you will need to read and sign before the start of the test.

RISK AND DISCOMFORTS

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorders of heart beat, and in very rare instances, heart attack, stroke or death. Every effort will be made to prevent these by preliminary screening and careful monitoring during the test. Should you feel any symptoms of discomfort of any kind, indicate this to us and we will terminate the test immediately.

RESPONSIBILITIES OF THE PARTICIPANT

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. You are responsible to fully disclose such information on the accompanying sheets or when requested by the testing staff. Furthermore you are expected to disclose any feelings of discomfort during the exercise test. The staff will take all reasonable precautions to ensure the safety and value of your exercise test but we can not be held responsible in the event that you fail to disclose important information to us.

BENEFITS TO BE EXPECTED

Results of the research will be used to design a safe, effective and reliable exercise test for the estimation of VO_2max in CRS clients. Your participation will contribute to the bank of data from which the test will be formulated. In addition to your contribution to the research data, you will also have the opportunity to have your personal fitness measured and you will receive feedback from us on the type and intensity of exercise that you can safely engage in.

CONFIDENTIALITY

Your privacy and wellbeing will be protected at all times. No data will be published or released to a third party without your permission.

INQUIRIES

Any questions about the procedures used in the graded exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations.

MEDICAL SUPERVISION

Your cardiovascular risk factor and medical history do not indicate a need for a physician to be in attendance during this fitness test. However, we will arrange for a medically supervised test if you prefer.

FREEDOM OF CONSENT

Your permission to perform this graded exercise test is voluntary. You are free to deny consent now or withdraw consent at any time (including during the exercise test) if you so desire.

SUBJECT'S CONSENT

I have read this form and I understand the test procedures and the conditions under which this test will be conducted. I consent to participate in this fitness test without/with medical supervision (delete inapplicable words).

.....	.....	.....
Name of Subject	Signature of Subject	Date

INFORMED CONSENT FOR SUBJECTS UNDER THE AGE OF 35 YEARS

Please return this Consent Form.

1. EXPLANATION OF THE GRADED EXERCISE TEST

You will perform a graded exercise test on the bicycle ergometer or a motor-driven treadmill. The exercise intensities will begin at a level you can easily accomplish and will be advanced in stages, depending on your functional capacity. We may stop the test at any time if signs or symptoms occur or you may stop whenever you wish to because of personal feelings of fatigue or discomfort. We do not wish you to exercise at a level which is abnormally uncomfortable for you; for maximum benefit from the test , exercise as long as is comfortable.

2. RISK AND DISCOMFORTS

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorders of heart beat, and in very rare instances, heart attack, stroke or death. Every effort will be made to prevent these by preliminary screening and careful monitoring during the test. Should you feel any symptoms of discomfort of any kind, indicate this to us and we will terminate the test immediately.

3. RESPONSIBILITIES OF THE PARTICIPANT

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. You are responsible to fully disclose such information on the accompanying sheets or when requested by the testing staff. Furthermore you are expected to disclose any feelings of discomfort during the exercise test. The staff will take all reasonable precautions to ensure the safety and value of your exercise test but we can not be held responsible in the event that you fail to disclose important information to us.

4. BENEFITS TO BE EXPECTED

The results obtained from the exercise test assist in the evaluation of the types of physical activities you might engage in with no or low hazards.

5. INQUIRIES

Any questions about the procedures used in the graded exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations.

6. MEDICAL SUPERVISION

Normally it is not necessary for someone under the age of 35 to need a doctor present for an exercise test. However if your cardiovascular risk factor and medical history indicate the need for medical coverage, we will arrange for a doctor to be present. Alternatively, we will arrange for a medically supervised test if you prefer it that way.

7. FREEDOM OF CONSENT

Your permission to perform this graded exercise test is voluntary. You are free to *deny consent now or withdraw consent at any time* (including during the exercise test) if you so desire.

I have read this form and I understand the test procedures and the conditions under which this test will be conducted. I consent to participate in this fitness test without medical supervision.

SUBJECT'S CONSENT

I have read this form and I understand the procedures involved and the conditions under which the tests will be conducted. I am under the age of 35 and consent to participate in this study **WITHOUT** medical supervision.

.....	.....	.....
Name of Subject	Signature of Subject	Date
.....	.....	.....
Name of Witness	Signature of Witness	Date

INFORMED CONSENT FOR SUBJECTS OVER THE AGE OF 35 YEARS

1. EXPLANATION OF THE GRADED EXERCISE TEST

You will perform a graded exercise test on the bicycle ergometer or a motor-driven treadmill. The exercise intensities will begin at a level you can easily accomplish and will be advanced in stages, depending on your functional capacity. We may stop the test at any time if signs or symptoms occur or you may stop whenever you wish to because of personal feelings of fatigue or discomfort. We do not wish you to exercise at a level which is abnormally uncomfortable for you; for maximum benefit from the test , exercise as long as is comfortable.

2. RISK AND DISCOMFORTS

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorders of heart beat, and in very rare instances, heart attack, stroke or death. Every effort will be made to prevent these by preliminary screening and careful monitoring during the test. Should you feel any symptoms of discomfort of any kind, indicate this to us and we will terminate the test immediately.

3. RESPONSIBILITIES OF THE PARTICIPANT

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. You are responsible to fully disclose such information on the accompanying sheets or when requested by the testing staff. Furthermore you are expected to disclose any feelings of discomfort during the exercise test. The staff will take all reasonable precautions to ensure the safety and value of your exercise test but we can not be held responsible in the event that you fail to disclose important information to us.

4. BENEFITS TO BE EXPECTED

The results obtained from the exercise test assist in the evaluation of the types of physical activities you might engage in with no or low hazards.

5. INQUIRIES

Any questions about the procedures used in the graded exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations.

6. FREEDOM OF CONSENT

Your permission to perform this graded exercise test is voluntary. You are *free to deny consent now or withdraw consent at any time* (including during the exercise test) if you so desire.

INFORMED CONSENT FOR SUBJECTS OVER THE AGE OF 35 YEARS

Please return this Consent Form.

You and your doctor will need to complete this form and return to us:

MEDICAL BACKGROUND and CONTRA-INDICATIONS TO EXERCISE

(i) details of any medical condition, disability or illness which make it unsafe for him/her to exercise at MAXIMAL INTENSITY.

_____

_____

(ii) details of exercises that are contra-indicated for each subject

_____

_____

(iii) prescribed drugs currently being taken

_____

(iv) any other information that you think will increase the safety for this subject to exercise.

_____

_____

SUBJECT'S CONSENT

I have read the information contained on this form and I understand the procedures involved and the conditions under which the tests will be conducted. I consent to participate WITHOUT/WITH medical supervision (delete inapplicable word).

....

Name of Subject Signature of Subject Date

DOCTOR'S CONSENT

I have read this form and, in my opinion, it is safe for this subject to participate in the tests WITHOUT/WITH medical supervision (delete inapplicable word).

....

Name of Doctor Signature of Doctor Date

VUT HUMAN PERFORMANCE UNIT
RISK FACTOR ASSESSMENT QUESTIONNAIRE

Please return this form to:

Dr. Steve Selig
Department of Physical Education & Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

Telephone: (03) 9688 4421 (direct)
Fax: (03) 9688 4891

NAME: ..... DATE: ..... SEX: M/F

AGE: ..... (Years) ADDRESS:.....

WEIGHT: .....(kg) HEIGHT: ..... (cm) POSTCODE: .....

TELEPHONE: Work: ..... Home: ..... FAX: .....

MEDICAL HISTORY:
In the past have you ever had (tick No or Yes)

	NO	YES		NO	YES
Stroke	☐	☐	Congential Heart Disease	☐	☐
Myocardial infarction (heart attack)	☐	☐	Disease of Arteries/Veins	☐	☐
Angina Pectoris	☐	☐	Asthma	☐	☐
Heart Murmur	☐	☐	Other Lung Disease (eg.emphysema)	☐	☐
Heart Rhythm Disturbance	☐	☐	Epilepsy	☐	☐
Rheumatic Fever	☐	☐	Injuries to back, knees, ankles	☐	☐

List any prescribed medications being taken

.....

.....

Other illness (Give details) .....

.....

.....

ALLERGIES: Do you have any allergies NO ☐ YES ☐

If yes, give details: .....

SYMPTOMS DURING OR AFTER EXERCISE
As a result of exercise, have you ever experienced any of the following:

	NO	YES		NO	YES
Pain or discomfort in the chest, back, arm, or jaw	☐	☐	Palpitations (heart rhythm disturbance) or racing heart rate	☐	☐
Severe shortness of breath or problems with breathing during mild exertion	☐	☐	Pain in the legs during mild exertion	☐	☐
Dizziness, nausea or fainting	☐	☐	Severe heat exhaustion (ie heat stroke)	☐	☐

CARDIOVASCULAR RISK FACTORS:

Do you have (tick No, Yes or circle?)	NO	YES	DON'T KNOW	
High Blood Pressure	☐	☐	?	
High Blood Cholesterol/Triglycerides	☐	☐	?	
Smoking Habit	☐	☐	Ex. Smoker	Average/day....
Diabetes	☐	☐	?	
Do you drink alcohol regularly	☐	☐		Average/day... (cont. overleaf)

Please turn over and provide the information requested overleaf.

FAMILY MEDICAL HISTORY:

Have members of your immediate family ever had any of the following conditions: (tick No, Yes or circle?).
If you answer Yes or ?, write beside this the member of the family affected (F=father, M=mother, B=brother, S=sister, GM= grandmother, GF=grandfather).

	NO	YES		FAMILY MEMBER	AGE (Years)	ALIVE NOW? (Y/N)
Myocardial infarction (heart attack)	☐	☐	?	_____	_____	_____
Angina Pectoris	☐	☐	?	_____	_____	_____
Stroke	☐	☐	?	_____	_____	_____
High Blood Pressure	☐	☐	?	_____	_____	_____
High Blood Cholesterol/Triglycerides	☐	☐	?	_____	_____	_____
Diabetes	☐	☐	?	_____	_____	_____
Cancer	☐	☐	?	_____	_____	_____

PERSONAL LIFESTYLE:

A. Exercise

List the sports, exercise or physically active hobbies (eg. gardening or playing with the kids) that you are currently engaged in:

Sport/Activity	Day(s) of week Sa-Su-Mo-Tu-We-Th-Fr	Time of the day eg. 6 p.m.	Approximate duration eg. 30 minutes
		TOTAL	

B. Nutrition

List a typical day's eating pattern.

Breakfast	Lunch	Dinner	Snacks	Drinks

C. Rest/Recreation

How many hours sleep do you usually have? .....hours/
On average how much time do you spend each day on passive hobbies or just relaxing ..... minutes/hours.
Do you feel that you usually get enough restful sleep and time to relax? Yes/No

Client Declaration

I declare that the above information is to my knowledge true and correct, and that I have not omitted any information that is requested on this form.

SIGNED:

DATE:

OFFICE USE ONLY

CLEARANCE TO UNDERGO AN EXERCISE TEST

This person has been cleared to undergo a fitness test:

- ☐ Without medical supervision
- ☐ With medical supervision
- ☐ A fitness test is not advisable at this time

Signed: Dr/Mr/Mrs/Ms .....
(Circle appropriate title:
Physician/exercise physiologist)

Please turn over and provide the information requested overleaf.

VUT HUMAN PERFORMANCE UNIT

INFORMED CONSENT FOR DRAWING A BLOOD SAMPLE

Please return this form to:

Dr. Steve Selig
Department of Physical Education & Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

Telephone: (03) 9688 4421 (direct)
Fax: (03) 9688 4891

With your informed consent, we would like to take a blood sample(s) for the following purpose:

- ☐ to assess your fitness level (eg. lactate).
- ☐ to assess your health status (eg. cholesterol)
- ☐ as part of a research project.
- ☐ as part of a student laboratory session.

Due to the nature of the tests, we suggest that the following method of blood sampling would be most appropriate in your case.

- ☐ **skinprick** of a finger tip, using an Autoclix (similar to test kit used by diabetics). You will feel a small prick on your finger tip when the sample is taken.
- ☐ **venepuncture**, which involves a needle prick into a vein in your arm; a sample (up to 8 ml) is then drawn off into a plastic container called a vacutainer. We use needles with small diameters in order to minimize the discomfort to you.
- ☐ **venous catheterisation** which involves the introduction of a small plastic tube or catheter (up to 2 inches long) into a vein in your arm, again using a needle to introduce the catheter. In this case, the catheter will usually be left in your arm for the duration of the tests, (approx._____ hours/minutes). Only the plastic tube is left in your arm... the needle is withdrawn as soon as the catheter is in place. Catheters are used when several blood samples are needed from one site, because once the catheter is in place, it is a simple and painless procedure to remove a blood sample. The total amount of blood taken over all the samples will not exceed ___ ml which is less than 2% of your total blood volume and is less than 10% of the volume drawn out of a blood donor. In between each sample, the catheter will be filled with heparinised saline; this solution has anti-clotting agent in it to keep the catheter open but is otherwise like normal blood plasma and will not cause any harmful side-effects.

PRECAUTIONS TAKEN

A. **Venepuncture and/or Venous Catheterisation**

1. We only use clean equipment and safe (ie. for you and us) techniques. The risk of cross-infection is negligible. For venepuncture and venous catheterisation, only sterile unused needles, plastic tubing, syringes, dressings and heparinised saline (catheterisation only) are used.

2. Only staff who have completed the Pathology Assistant Course (RMIT) or equivalent qualification will be entitled to take your blood sample(s). If you are unsure of the qualifications of the staff member attending to you, do not hesitate to ask for evidence of qualification.

B. **Skinprick**

Staff and some students have been trained to take a blood sample by skinprick using clean and safe (ie. for you and the staff) techniques. The risk of cross-infection is negligible.

C. **Fainting**

Occassionally people faint when having a blood sample taken. Staff in our laboratory are trained to deal with fainting. As extra precaution, we have oxygen treatment available at any time.

D. **Bruising**

Occasionally bruising may occur as a result of blood sampling, but we practise techniques that minimize this problem. Should bruising occur however, it should resolve within 1-2 days. If swelling and tenderness occurs, please let us know immediately; if you are unable to contact us, you should consult with your doctor as quickly as possible.

Please turn over and provide the information requested overleaf.

RISK FACTOR ASSESSMENT FOR BLOOD SAMPLING

	TICK RESPONSE		
	Yes	No	
Have you ever fainted when you have had an injection or blood sample taken.	☐	☐	
Do you have any of the following conditions?			Not Likely
- Bleeding disorders (eg. hemophilia)	☐	☐	☐
- Clotting problems	☐	☐	☐
- H.I.V. positive (the A.I.D.S. virus)	☐	☐	☐
- Hepatitis B or C	☐	☐	☐
Have you ever been prescribed drugs to prevent blood clotting? (eg. warfarin, heparin).	☐	☐	☐

If yes to any of the above, give details: .....

.....

.....

CLIENT DECLARATION AND CONSENT

I have read the information overleaf and provided complete and accurate details under the Risk Factor Assessment. Furthermore, I consent to having a blood sample(s) taken by the method indicated overleaf.

Name: .....

Signed: ..... Date: .....

Witness: ..... Date: .....

OFFICE USE ONLY

CLEARANCE TO UNDERGO A BLOOD SAMPLING PROCEDURE

This person has been cleared to undergo a blood sampling procedure by:

- ☐ Skinprick
- ☐ Venepuncture
- ☐ Venons catheterisation
- ☐ A blood sampling procedure is not advisable at this time

Signed: Dr/Mr/Mrs/Ms _____ Date: _____

Circle appropriate title: physician/exercise physiologist

Please turn over and provide the information requested overleaf.

VICTORIA UNIVERSITY OF TECHNOLOGY
Exercise Test Appointment Sheet

NAME: .....

DATE OF APPOINTMENT: .....

TIME OF APPOINTMENT: .....

ADDRESS: Room L305
Department of Physical Education and Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

PHONE NO: (03) 9688 4421 (Dr. Steve Selig)

FAX: (03) 9688 4891

INSTRUCTIONS:

1. Do not exercise on day to test.
2. If exercising on day before test then make it light exercise.
3. Eat a light meal 2-3 hours prior to the test, or as directed. Avoid coffee, tea, alcohol and non-prescription drugs for three hours prior to the test.
4. Bring running shoes and shorts, or tracksuit.
5. Females wear bikini top or sports bra. Wear a T-shirt over the top.
6. Change and shower facilities are available (bring towel.)
7. Return any other papers that have been sent to you, and ensure that you have supplied the information where indicated and signed the forms.
8. Medical Supervision: if you are **under 35 years**, then you will not normally need medical supervision; however we will arrange for medical supervision if you prefer or if your risk factors or medical history indicate the need for supevision. If you are **over 35 years**, you will require medical supervision unless your doctor is willing to give consent to you exercising at maximal intensity without medical supervision.
8. Car parking: .....
9. Other instructions: .....

Victoria University of Technology
Ballarat Road
Footscray
PO Box 14428
MMC
Melbourne
Victoria 3000
Australia

Telephone
(03) 688 4000

Facsimile
(03) 689 4069

Footscray Campus
Department of
Physical Education
and Recreation

Telephone
(03) 688 4470
(03) 688 4473

Facsimile
(03) 688 4891

VICTORIA UNIVERSITY OF TECHNOLOGY

STANDARD CONSENT FORM FOR SUBJECTS INVOLVED IN EXPERIMENTS

VICTORIA UNIVERSITY OF TECHNOLOGY

CERTIFICATION BY SUBJECT

I,
of
certify that I have the legal ability to give valid consent and that I am voluntarily giving my consent to participate in the experiment entitled :

Development of a protocol for the prediction of the aerobic power, using a sub-maximal graded step test.

being conducted at Victoria University of Technology by :

I certify that the objectives of the experiment, together with any risks to me associated with the procedures listed hereunder to be carried out in the experiment, have been fully explained to me by :

Dr.Steve Selig

and that I freely consent to participation involving the use on me of these procedures.

Procedures
Risk Factor Assessment
Exercise test: incremental test up to VO_2max
Venepuncture
Monitoring of ECG, blood pressure, heart rate and rhythm, perceived exertion, lung ventilation before, during and after exercise test.

I certify that I have had the opportunity to have my questions answered and that I understand that I can withdraw from the experiment at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the confidentiality of the information I provide will be safeguarded.

Signed : .....)
)
Witness other than the experimenter :) Date : .....
)
.....)

INFORMATION SHEET for subjects participating in a research project entitled

"Development of a protocol for the prediction of aerobic power, using a sub-maximal graded step test".

THE SUBJECTS' DOCTORS WILL ALSO NEED TO READ THIS AND SIGN THE CONSENT FORMS WHERE APPLICABLE.

This research has been commissioned by the Commonwealth Rehabilitation Service to devise an exercise test which will be subsequently used by the CRS to estimate a client's aerobic fitness (indexed by maximal oxygen uptake, VO_2max). The research project will require subjects to perform a graded step test (using Reebok steps) beginning at a moderate level of intensity and progressing up to their personal maximal exertion level which will they need to sustain for a period of approx. 2 minutes. From the results of the research, we aim to design a sub-maximal version of the test which we hope will be widely used by CRS as a simple, safe and effective method of assessing VO_2max and, in this way, measuring the progress that clients are making in their fitness programs.

TEST PROTOCOL

The test will begin at an easy intensity and then the intensity will increase gradually according to the following plan:

** *Time (minutes)*	*Step Height (cm)*	*Stepping frequency = the number of the following cycles per minute:* UP-UP-DOWN-DOWN	*Additional Load to weighted vest or belt (kgs)*
0 to 1	≡ 0.125 x height of the subject	14	0
1 to 2	≡ 0.125 x height of the subject	18	0
2 to 3	≡ 0.125 x height of the subject	22	0
3 to 4	≡ 0.125 x height of the subject	26	0
4 to 5	≡ 0.125 x height of the subject	30	0
5 to 6	≡ 0.125 x height of the subject	34	0
6 to 7	≡ 0.125 x height of the subject	34	2
7 to 8	≡ 0.125 x height of the subject	34	4
8 to 9	≡ 0.125 x height of the subject	34	6
9 etc.until VO_2max is reached	≡ 0.125 x height of the subject	34	8, etc. until VO_2max is reached

** The duration of the test will vary between each individual; the fitter you are, the longer the test will last and vice versa. We may stop the test at any time if signs or symptoms occur that indicate that it is wise to stop; alternatively you may stop whenever you wish if you feel tired, uncomfortable or distressed. We want you to exercise as long as you are able, with the ideal situation (from the point of view of the research) being that you reach your personal maximal aerobic power (VO_2max) during the last two minutes of the test. However, we will stop the test when you reach *any one of the following criteria* for stopping:

(i) you wish to stop

(ii) you experience chest pain (typical of angina), severe shortness of breath or any other pain related to, or caused by the exercise.

(iii) you wish to continue but there are abnormal changes to the ECG or blood pressure responses or other signs of cardiorespiratory distress are evident (eg facial pallor)

(iv) you perceive that you are working maximally

(v) your respiratory exchange ratio has reached 1.10

(vi) you reach VO_2max (indicated by no further increases in VO_2 for two successive workloads).

OTHER PROCEDURES

For safety, your blood pressure will be measured prior to, and at the end of the test and your ECG (for heart rate and heart rhythm) and breathing will be monitored throughout. In order to monitor breathing, you will need to wear a valve in your mouth and have a nose clip fitted. This normally doesn't cause any distress, but if it is does in your case, then you need to tell us immediately. You will also be asked frequently during the test about how you are feeling *in general* (breathing, legs, back, etc.) and it is important that you respond accurately to this. Hand signals will be standardised to help communicate during the exercise.

BLOOD SAMPLING

Prior to the test, some subjects will have a catheter inserted into a superficial vein in the forearm. Once the catheter is in place, it is a simple and painless procedure to draw blood samples. This will allow us to measure some of the changes in the blood that happen in response to the exercise. *This does / does not apply to you* (delete the inapplicable words). If you are going to have a catheter inserted, then there is a separate informed consent form (attached) that you will need to read and sign before the start of the test.

RISK AND DISCOMFORTS

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorders of heart beat, and in very rare instances, heart attack, stroke or death. Every effort will be made to prevent these by preliminary screening and careful monitoring during the test. Should you feel any symptoms of discomfort of any kind, indicate this to us and we will terminate the test immediately.

RESPONSIBILITIES OF THE PARTICIPANT

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. You are responsible to fully disclose such information on the accompanying sheets or when requested by the testing staff. Furthermore you are expected to disclose any feelings of discomfort during the exercise test. The staff will take all reasonable precautions to ensure the safety and value of your exercise test but we can not be held responsible in the event that you fail to disclose important information to us.

BENEFITS TO BE EXPECTED

Results of the research will be used to design a safe, effective and reliable exercise test for the estimation of VO_2max in CRS clients. Your participation will contribute to the bank of data from which the test will be formulated. In addition to your contribution to the research data, you will also have the opportunity to have your personal fitness measured and you will receive feedback from us on the type and intensity of exercise that you can safely engage in.

CONFIDENTIALITY

Your privacy and wellbeing will be protected at all times. No data will be published or released to a third party without your permission.

INQUIRIES

Any questions about the procedures used in the graded exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations.

MEDICAL SUPERVISION

Before you can be enrolled in this study, we require that your doctor consent to your involvement. In some cases, this may only be given on the condition that a medical practitioner is present during the exercise test.

FREEDOM OF CONSENT

Your permission to perform this graded exercise test is voluntary. You are free to deny consent now or withdraw consent at any time (including during the exercise test) if you so desire.

SUBJECT'S CONSENT

I have read this form and I understand the test procedures and the conditions under which this test will be conducted. I consent to participate in this fitness test without/with medical supervision (delete inapplicable words).

.....	.....	.....
Name of Subject	Signature of Subject	Date

MEDICAL BACKGROUND and CONTRA-INDICATIONS TO EXERCISE for CRS clients participating in a research project entitled *"Development of a protocol for the prediction of aerobic power, using a sub-maximal graded step test"*:

Apart from medical clearance to undergo the testing, we also require that the following information be supplied to us:

(i) details of the CRS clients' rehabilitation condition, disability or illness

_____

_____

(ii) details of exercises that are contra-indicated for each client

_____

_____

(iii) prescribed drugs currently being taken

_____

_____

(iv) other illnesses or injuries that the clients have suffered in the past that may adversely affect their capacity for exercise and/or fitness levels.

_____

_____

(v) any other information that you think will increase the safety of testing of this client.

_____

_____

DOCTOR'S CONSENT

I have read this form and, in my opinion, it is safe for this subject to participate in the study without/with medical supervision (delete inapplicable words).

.....	.....	.....
Name of Doctor	Signature of Doctor	Date

VUT HUMAN PERFORMANCE UNIT
RISK FACTOR ASSESSMENT QUESTIONNAIRE

Please return this form to:

Dr. Steve Selig
Department of Physical Education & Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

Telephone: (03) 9688 4421 (direct)
Fax: (03) 9688 4891

NAME: ..... DATE: ..... SEX: M/F

AGE: ..... (Years) ADDRESS: .....

WEIGHT: .....(kg) HEIGHT: ..... (cm) POSTCODE: .....

TELEPHONE: Work: ..... Home: ..... FAX: .....

MEDICAL HISTORY:
In the past have you ever had (tick No or Yes)

	NO	YES		NO	YES
Stroke	☐	☐	Congential Heart Disease	☐	☐
Myocardial infarction (heart attack)	☐	☐	Disease of Arteries/Veins	☐	☐
Angina Pectoris	☐	☐	Asthma	☐	☐
Heart Murmur	☐	☐	Other Lung Disease (eg.emphysema)	☐	☐
Heart Rhythm Disturbance	☐	☐	Epilepsy	☐	☐
Rheumatic Fever	☐	☐	Injuries to back, knees, ankles	☐	☐

List any prescribed medications being taken ..... Other illness (Give details) .....

.....

.....

ALLERGIES: Do you have any allergies NO ☐ YES ☐

If yes, give details: .....

SYMPTOMS DURING OR AFTER EXERCISE
As a result of exercise, have you ever experienced any of the following:

	NO	YES		NO	YES
Pain or discomfort in the chest, back, arm, or jaw	☐	☐	Palpitations (heart rhythm disturbance) or racing heart rate	☐	☐
Severe shortness of breath or problems with breathing during mild exertion	☐	☐	Pain in the legs during mild exertion	☐	☐
Dizziness, nausea or fainting	☐	☐	Severe heat exhaustion (ie heat stroke)	☐	☐

CARDIOVASCULAR RISK FACTORS:

Do you have (tick No, Yes or circle?)	NO	YES	DON'T KNOW	
High Blood Pressure	☐	☐	?	
High Blood Cholesterol/Triglycerides	☐	☐	?	
Smoking Habit	☐	☐	Ex. Smoker	Average/day....
Diabetes	☐	☐	?	
Do you drink alcohol regularly	☐	☐		Average/day... (cont. overleaf)

Please turn over and provide the information requested overleaf.

FAMILY MEDICAL HISTORY:

Have members of your immediate family ever had any of the following conditions: (tick No, Yes or circle?).
If you answer Yes or ?, write beside this the member of the family affected (F=father, M=mother, B=brother, S=sister, GM= grandmother, GF=grandfather).

	NO	YES		FAMILY MEMBER	AGE (Years)	ALIVE NOW? (Y/N)
Myocardial infarction (heart attack)	☐	☐	?	_____	_____	_____
Angina Pectoris	☐	☐	?	_____	_____	_____
Stroke	☐	☐	?	_____	_____	_____
High Blood Pressure	☐	☐	?	_____	_____	_____
High Blood Cholesterol/Triglycerides	☐	☐	?	_____	_____	_____
Diabetes	☐	☐	?	_____	_____	_____
Cancer	☐	☐	?	_____	_____	_____

PERSONAL LIFESTYLE:

A. Exercise

List the sports, exercise or physically active hobbies (eg. gardening or playing with the kids) that you are currently engaged in:

Sport/Activity	Day(s) of week Sa-Su-Mo-Tu-We-Th-Fr	Time of the day eg. 6 p.m.	Approximate duration eg. 30 minutes
		TOTAL	

B. Nutrition

List a typical day's eating pattern.

Breakfast	Lunch	Dinner	Snacks	Drinks

C. Rest/Recreation

How many hours sleep do you usually have? .....hours/
On average how much time do you spend each day on passive hobbies or just relaxing ..... minutes/hours.
Do you feel that you usually get enough restful sleep and time to relax? Yes/No

Client Declaration

I declare that the above information is to my knowledge true and correct, and that I have not omitted any information that is requested on this form.

SIGNED:

DATE:

OFFICE USE ONLY

CLEARANCE TO UNDERGO AN EXERCISE TEST

This person has been cleared to undergo a fitness test:

☐ Without medical supervision
☐ With medical supervision
☐ A fitness test is not advisable at this time

Signed: Dr/Mr/Mrs/Ms .....
(Circle appropriate title:
Physician/exercise physiologist)

Please turn over and provide the information requested overleaf.

VUT HUMAN PERFORMANCE UNIT

INFORMED CONSENT FOR DRAWING A BLOOD SAMPLE

Please return this form to:

Dr. Steve Selig
Department of Physical Education & Recreation
Victoria University of Technology
PO Box 14428
MCMC MELBOURNE 8001

Telephone: (03) 9688 4421 (direct)
Fax: (03) 9688 4891

With your informed consent, we would like to take a blood sample(s) for the following purpose:

- ☐ to assess your fitness level (eg. lactate).
- ☐ to assess your health status (eg. cholesterol)
- ☐ as part of a research project.
- ☐ as part of a student laboratory session.

Due to the nature of the tests, we suggest that the following method of blood sampling would be most appropriate in your case.

- ☐ skinprick of a finger tip, using an Autoclix (similar to test kit used by diabetics). You will feel a small prick on your finger tip when the sample is taken.
- ☐ venepuncture, which involves a needle prick into a vein in your arm; a sample (up to 8 ml) is then drawn off into a plastic container called a vacutainer. We use needles with small diameters in order to minimize the discomfort to you.
- ☐ venous catheterisation which involves the introduction of a small plastic tube or catheter (up to 2 inches long) into a vein in your arm, again using a needle to introduce the catheter. In this case, the catheter will usually be left in your arm for the duration of the tests, (approx._____ hours/minutes). Only the plastic tube is left in your arm... the needle is withdrawn as soon as the catheter is in place. Catheters are used when several blood samples are needed from one site, because once the catheter is in place, it is a simple and painless procedure to remove a blood sample. The total amount of blood taken over all the samples will not exceed ___ ml which is less than 2% of your total blood volume and is less than 10% of the volume drawn out of a blood donor. In between each sample, the catheter will be filled with heparinised saline; this solution has anti-clotting agent in it to keep the catheter open but is otherwise like normal blood plasma and will not cause any harmful side-effects.

PRECAUTIONS TAKEN

A. Venepuncture and/or Venous Catheterisation

1. We only use clean equipment and safe (ie. for you and us) techniques. The risk of cross-infection is negligible. For venepuncture and venous catheterisation, only sterile unused needles, plastic tubing, syringes, dressings and heparinised saline (catheterisation only) are used.

2. Only staff who have completed the Pathology Assistant Course (RMIT) or equivalent qualification will be entitled to take your blood sample(s). If you are unsure of the qualifications of the staff member attending to you, do not hesitate to ask for evidence of qualification.

B. Skinprick

Staff and some students have been trained to take a blood sample by skinprick using clean and safe (ie. for you and the staff) techniques. The risk of cross-infection is negligible.

C. Fainting

Occassionally people faint when having a blood sample taken. Staff in our laboratory are trained to deal with fainting. As extra precaution, we have oxygen treatment available at any time.

D. Bruising

Occasionally bruising may occur as a result of blood sampling, but we practise techniques that minimize this problem. Should bruising occur however, it should resolve within 1-2 days. If swelling and tenderness occurs, please let us know immediately; if you are unable to contact us, you should consult with your doctor as quickly as possible.

Please turn over and provide the information requested overleaf.

RISK FACTOR ASSESSMENT FOR BLOOD SAMPLING

	TICK RESPONSE		
	Yes	No	
Have you ever fainted when you have had an injection or blood sample taken.	☐	☐	
Do you have any of the following conditions?			Not Likely
- Bleeding disorders (eg. hemophilia)	☐	☐	☐
- Clotting problems	☐	☐	☐
- H.I.V. positive (the A.I.D.S. virus)	☐	☐	☐
- Hepatitis B or C	☐	☐	☐
Have you ever been prescribed drugs to prevent blood clotting? (eg. warfarin, heparin).	☐	☐	☐

If yes to any of the above, give details: .....

.....

.....

CLIENT DECLARATION AND CONSENT

I have read the information overleaf and provided complete and accurate details under the Risk Factor Assessment. Furthermore, I consent to having a blood sample(s) taken by the method indicated overleaf.

Name: .....

Signed: ..... Date: .....

Witness: ..... Date: .....

OFFICE USE ONLY

CLEARANCE TO UNDERGO A BLOOD SAMPLING PROCEDURE

This person has been cleared to undergo a blood sampling procedure by:

- ☐ Skinprick
- ☐ Venepuncture
- ☐ Venons catheterisation
- ☐ A blood sampling procedure is not advisable at this time.

Signed: Dr/Mr/Mrs/Ms _____ Date: _____

Circle appropriate title: physician/exercise physiologist

Please turn over and provide the information requested overleaf.

Appendix C
Borg Scale of Perceived Exertion (RPE)

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

(Adapted from Borg, 1982)

Appendix D
(Statistical Outputs)

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. VO2_MLS

Block Number 1. Method: Enter
A_AMNSQ HR_HMNSQ WT_WMNSQ T_T.WT_W HEARTR HR_H.S_S T_TMNSQ SEX
AGE WEIGHT T_T.S_S TIME HR_H.W_W HR_H.T_T A_A.HR_H A_A.WT_W
A_A.T_T WT_W.S_S

Variable(s) Entered on Step Number
1.. WT_W.S_S
2.. T_TMNSQ
3.. AGE
4.. HR_H.W_W
5.. A_A.WT_W
6.. T_T.S_S
7.. A_A.HR_H
8.. HR_HMNSQ
9.. A_AMNSQ
10.. HEARTR
11.. WT_WMNSQ
12.. WEIGHT
13.. TIME
14.. HR_H.S_S
15.. A_A.T_T
16.. T_T.WT_W
17.. SEX
18.. HR_H.T_T

Multiple R	.96824
R Square	.93750
Adjusted R Square	.93047
Standard Error	2.03500

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	18	9938.57957	552.14331
Residual	160	662.59915	4.14124

F = 133.32786 Signif F = .0000

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. VO2_MLS

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

Variable	B	SE B	Beta	T	Sig T
A_AMNSQ	-.009631	.003106	-.109267	-3.101	.0023
HR_HMNSQ	8.42794E-05	5.5048E-04	.008375	.153	.8785
WT_WMNSQ	.004522	9.2871E-04	.170904	4.869	.0000
T_T.WT_W	-.029005	.011361	-.200418	-2.553	.0116
HEARTR	.069470	.019382	.243814	3.584	.0004
HR_H.S_S	.069577	.042525	.102053	1.636	.1038
T_TMNSQ	-.155439	.048931	-.216895	-3.177	.0018
SEX	4.193802	2.221923	.206213	1.887	.0609
AGE	.001976	.045341	.002078	.044	.9653
WEIGHT	-.202984	.048147	-.422269	-4.216	.0000
T_T.S_S	.075282	.428101	.013931	.176	.8606
TIME	1.305555	.168959	.481669	7.727	.0000

HR_H.W_W	.001034	.001032	.057852	1.003	.3176
HR_H.T_T	-.001320	.009688	-.014993	-.136	.8918
A_A.HR_H	-5.69312E-04	.001264	-.016021	-.450	.6531
A_A.WT_W	.001915	.001393	.033309	1.374	.1713
A_A.T_T	-.005851	.013588	-.021701	-.431	.6673
WT_W.S_S	-.122255	.120339	-.092059	-1.016	.3112
(Constant)	19.074937	3.010258		6.337	.0000

End Block Number 1 All requested variables entered.

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. VO2_MLS

Block Number 1. Method: Enter
A_AMNSQ HR_HMNSQ WT_WMNSQ T_T.WT_W HEARTR HR_H.S_S T_TMNSQ SEX
AGE WEIGHT T_T.S_S TIME HR_H.W_W HR_H.T_T A_A.HR_H A_A.WT_W
A_A.T_T WT_W.S_S

Variable(s) Entered on Step Number
1.. WT_W.S_S
2.. AGE
3.. HR_H.S_S
4.. WT_WMNSQ
5.. A_AMNSQ
6.. HR_HMNSQ
7.. T_T.S_S
8.. WEIGHT
9.. T_TMNSQ
10.. A_A.HR_H
11.. HEARTR
12.. HR_H.T_T
13.. SEX
14.. HR_H.W_W
15.. T_T.WT_W
16.. A_A.T_T
17.. TIME
18.. A_A.WT_W

Multiple R	.95423
R Square	.91055
Adjusted R Square	.90591
Standard Error	2.72469

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	18	26222.26437	1456.79246
Residual	347	2576.11118	7.42395

F = 196.22871 Signif F = .0000

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. VO2_MLS

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

Variable	B	SE B	Beta	T	Sig T
A_AMNSQ	.005430	.001644	.063476	3.304	.0011
HR_HMNSQ	-8.40248E-04	2.1644E-04	-.083870	-3.882	.0001
WT_WMNSQ	-.003229	.001503	-.056827	-2.148	.0324
T_T.WT_W	2.80598E-05	4.5999E-05	.020805	.610	.5423
HEARTR	-.043247	.011258	-.147022	-3.841	.0001
HR_H.S_S	.025305	.011710	.040181	2.161	.0314
T_TMNSQ	-.127789	.011171	-.316280	-11.440	.0000
SEX	3.171331	.499003	.178748	6.355	.0000
AGE	-.047453	.016519	-.057978	-2.873	.0043
WEIGHT	-.113182	.024807	-.149111	-4.563	.0000
T_T.S_S	-8.69562E-05	3.7334E-04	-.008885	-.233	.8160
TIME	2.424061	.094642	1.205353	25.613	.0000

HR_H.W_W	3.27240E-11	1.4355E-11	.068912	2.280	.0232
HR_H.T_T	1.90919E-08	1.1570E-07	.009625	.165	.8690
A_A.HR_H	2.20883E-04	8.4658E-04	.008675	.261	.7943
A_A.WT_W	1.38416E-04	8.8771E-04	.010477	.156	.8762
A_A.T_T	-9.19839E-04	.006587	-.005039	-.140	.8890
WT_W.S_S	-7.14808E-06	1.2748E-05	-.015610	-.561	.5753
(Constant)	26.978100	2.470943		10.918	.0000

End Block Number 1 All requested variables entered.

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. VO2_MLS

Block Number 1. Method: Enter
A_AMNSQ HR_HMNSQ WT_WMNSQ T_T.WT_W HEARTR HR_H.S_S T_TMNSQ SEX
AGE WEIGHT T_T.S_S TIME HR_H.W_W HR_H.T_T A_A.HR_H A_A.WT_W
A_A.T_T WT_W.S_S

Variable(s) Entered on Step Number
1.. WT_W.S_S
2.. WT_WMNSQ
3.. AGE
4.. HR_H.S_S
5.. A_AMNSQ
6.. HR_HMNSQ
7.. WEIGHT
8.. T_T.S_S
9.. TIME
10.. HR_H.W_W
11.. A_A.HR_H
12.. T_TMNSQ
13.. SEX
14.. HR_H.T_T
15.. HEARTR
16.. A_A.T_T
17.. T_T.WT_W
18.. A_A.WT_W

Multiple R	.94977
R Square	.90206
Adjusted R Square	.89871
Standard Error	2.86445

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	18	39750.74625	2208.37479
Residual	526	4315.85545	8.20505

F = 269.14830 Signif F = .0000

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. VO2_MLS

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

Variable	B	SE B	Beta	T	Sig T
A_AMNSQ	.005284	.001378	.060914	3.834	.0001
HR_HMNSQ	-5.15876E-04	1.8390E-04	-.048793	-2.805	.0052
WT_WMNSQ	.001074	6.7911E-04	.025920	1.581	.1144
T_T.WT_W	1.07769E-05	4.7090E-05	.006544	.229	.8191
HEARTR	-.007548	.008551	-.024774	-.883	.3778
HR_H.S_S	.036751	.009902	.054094	3.711	.0002
T_TMNSQ	-.115550	.009457	-.250060	-12.219	.0000
SEX	3.613792	.391133	.195930	9.239	.0000
AGE	-.061494	.014342	-.070495	-4.288	.0000
WEIGHT	-.103441	.014257	-.154960	-7.256	.0000

T_T.S_S	1.31791E-04	3.6459E-04	.011060	.361	.7179
TIME	2.218692	.068672	1.028522	32.308	.0000
HR_H.W_W	1.99431E-11	1.0238E-11	.034155	1.948	.0520
HR_H.T_T	2.18154E-08	1.0665E-07	.008906	.205	.8380
A_A.HR_H	-3.62967E-04	7.1245E-04	-.012675	-.509	.6106
A_A.WT_W	8.23938E-05	7.7559E-04	.005118	.106	.9154
A_A.T_T	.001748	.005849	.008437	.299	.7652
WT_W.S_S	-6.68670E-06	1.3059E-05	-.011829	-.512	.6088
(Constant)	21.177052	1.414538		14.971	.0000

End Block Number 1 All requested variables entered.

	Heart Rate	*Heart Rate 2*	
Mean	146.0	141.7	-2.9%
Variance	865.95294	973.839672	
Observations	86	86	
Pearson Corr	0.9821715		
Hypothesized	0		
df	85		
t Stat	6.586013		
P(T<=t) one-t	1.783E-09		
t Critical one-t	1.6629792		
P(T<=t) two-ta	3.565E-09		
t Critical two-t	1.9882691		
t-Test: Paired Two Sample for Means			
	True VO2 1	*True VO2 2*	
Mean	30.494035	29.1325587	-4.5%
Variance	78.705957	80.3669789	
Observations	83	83	
Pearson Corr	0.9774423		
Hypothesized	0		
df	82		
t Stat	6.5402031		
P(T<=t) one-t	2.46E-09		
t Critical one-t	1.6636477		
P(T<=t) two-ta	4.921E-09		
t Critical two-t	1.9893196		

- -

* * * * * * Analysis of Variance * * * * * *

46 cases accepted.
0 cases rejected because of out-of-range factor values.
0 cases rejected because of missing data.
2 non-empty cells.

1 design will be processed.

- -

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

Tests of Between-Subjects Effects.

Tests of Significance for T1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1866.96	44	42.43		
GROUP	.10	1	.10	.00	.961

- -

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

Tests involving 'ALGORITH' Within-Subject Effect.

Mauchly sphericity test, W = .41753
Chi-square approx. = 37.31383 with 5 D. F.
Significance = .000

Greenhouse-Geisser Epsilon = .73979
Huynh-Feldt Epsilon = .79855
Lower-bound Epsilon = .33333

AVERAGED Tests of Significance that follow multivariate tests are equivalent to univariate or split-plot or mixed-model approach to repeated measures.
Epsilons may be used to adjust d.f. for the AVERAGED results.

- -

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

EFFECT .. GROUP BY ALGORITH
Multivariate Tests of Significance (S = 1, M = 1/2, N = 20)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.47170	12.50032	3.00	42.00	.000
Hotellings	.89288	12.50032	3.00	42.00	.000
Wilks	.52830	12.50032	3.00	42.00	.000
Roys	.47170				

Note.. F statistics are exact.

- -

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

EFFECT .. ALGORITH
Multivariate Tests of Significance (S = 1, M = 1/2, N = 20)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F

Pillais	.57740	19.12839	3.00	42.00	.000
Hotellings	1.36631	19.12839	3.00	42.00	.000
Wilks	.42260	19.12839	3.00	42.00	.000
Roys	.57740				

Note.. F statistics are exact.

- -

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

Tests involving 'ALGORITH' Within-Subject Effect.

AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1398.23	132	10.59		
ALGORITH	637.98	3	212.66	20.08	.000
GROUP BY ALGORITH	458.55	3	152.85	14.43	.000

- -

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

Tests involving 'TIME' Within-Subject Effect.

Mauchly sphericity test, W = .01492
Chi-square approx. = 177.02639 with 14 D. F.
Significance = .000

Greenhouse-Geisser Epsilon = .35235
Huynh-Feldt Epsilon = .37426
Lower-bound Epsilon = .20000

AVERAGED Tests of Significance that follow multivariate tests are equivalent to univariate or split-plot or mixed-model approach to repeated measures. Epsilons may be used to adjust d.f. for the AVERAGED results.

- -

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

EFFECT .. GROUP BY TIME
Multivariate Tests of Significance (S = 1, M = 1 1/2, N = 19)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.17449	1.69095	5.00	40.00	.159
Hotellings	.21137	1.69095	5.00	40.00	.159
Wilks	.82551	1.69095	5.00	40.00	.159
Roys	.17449				

Note.. F statistics are exact.

- -

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

EFFECT .. TIME
Multivariate Tests of Significance (S = 1, M = 1 1/2, N = 19)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.99589	1937.94424	5.00	40.00	.000
Hotellings	242.24303	1937.94424	5.00	40.00	.000
Wilks	.00411	1937.94424	5.00	40.00	.000
Roys	.99589				

Note.. F statistics are exact.

- -

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

Tests involving 'TIME' Within-Subject Effect.

AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	305.38	220	1.39		
TIME	29765.81	5	5953.16	4288.74	.000
GROUP BY TIME	8.60	5	1.72	1.24	.292

- -

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

Tests involving 'ALGORITH BY TIME' Within-Subject Effect.

Mauchly sphericity test, W = .00000
Chi-square approx. = . with 119 D. F.
Significance = .

Greenhouse-Geisser Epsilon = .26725
Huynh-Feldt Epsilon = .30408
Lower-bound Epsilon = .06667

AVERAGED Tests of Significance that follow multivariate tests are equivalent to univariate or split-plot or mixed-model approach to repeated measures. Epsilons may be used to adjust d.f. for the AVERAGED results.

- -

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

EFFECT .. GROUP BY ALGORITH BY TIME
Multivariate Tests of Significance (S = 1, M = 6 1/2, N = 14)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.46986	1.77257	15.00	30.00	.089
Hotellings	.88628	1.77257	15.00	30.00	.089
Wilks	.53014	1.77257	15.00	30.00	.089
Roys	.46986				

Note.. F statistics are exact.

- -

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

EFFECT .. ALGORITH BY TIME
Multivariate Tests of Significance (S = 1, M = 6 1/2, N = 14)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.98552	136.16642	15.00	30.00	.000
Hotellings	68.08321	136.16642	15.00	30.00	.000
Wilks	.01448	136.16642	15.00	30.00	.000
Roys	.98552				

Note.. F statistics are exact.

- -

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

Tests involving 'ALGORITH BY TIME' Within-Subject Effect.

AVERAGED Tests of Significance for MEAS.1 using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	430.18	660	.65		
ALGORITH BY TIME	84.96	15	5.66	8.69	.000
GROUP BY ALGORITH BY TIME	33.56	15	2.24	3.43	.000

- -

TUKEY: algorithm																									
MS-anova	**10.6**																								
df-anova	**88**																								
n	**46**																								
k = # means	**24**																								
alpha	**0.05**																								
critical value	**5.1**																								
Tukey value	**2.4**																								
		Rehab 1	Real 1	Norm 1	All 1	Rehab 2	All 2	Norm 2	Real 2	Rehab 3	All 3	Real 3	Norm 3	Rehab 4	Real 4	All 4	Norm 4	Rehab 5	All 5	Real 5	Norm 5	Rehab 6	All 6	Norm 6	Real 6
		9.69	10.72	11.17	11.29	13.05	14.87	15.01	15.76	16.21	18.19	18.24	18.52	19.21	20.99	21.29	21.69	22.05	24.04	24.16	24.35	24.62	26.46	26.57	27.60
Rehab 1	9.69	-	**1.0**	**1.5**	**1.6**	**3.4**	**5.2**	**5.3**	**6.1**	**6.5**	**8.5**	**8.6**	**8.8**	**9.5**	**11.3**	**11.6**	**12.0**	**12.4**	**14.4**	**14.5**	**14.7**	**14.9**	**16.8**	**16.9**	**17.9**
Real 1	10.72		-	**0.4**	**0.6**	**2.3**	**4.1**	**4.3**	**5.0**	**5.5**	**7.5**	**7.5**	**7.8**	**8.5**	**10.3**	**10.6**	**11.0**	**11.3**	**13.3**	**13.4**	**13.6**	**13.9**	**15.7**	**15.9**	**16.9**
Norm 1	11.17			-	**0.1**	**1.9**	**3.7**	**3.8**	**4.6**	**5.0**	**7.0**	**7.1**	**7.3**	**8.0**	**9.8**	**10.1**	**10.5**	**10.9**	**12.9**	**13.0**	**13.2**	**13.5**	**15.3**	**15.4**	**16.4**
All 1	11.29				-	**1.8**	**3.6**	**3.7**	**4.5**	**4.9**	**6.9**	**7.0**	**7.2**	**7.9**	**9.7**	**10.0**	**10.4**	**10.8**	**12.8**	**12.9**	**13.1**	**13.3**	**15.2**	**15.3**	**16.3**
Rehab 2	13.05					-	**1.8**	**2.0**	**2.7**	**3.2**	**5.1**	**5.2**	**5.5**	**6.2**	**7.9**	**8.2**	**8.6**	**9.0**	**11.0**	**11.1**	**11.3**	**11.6**	**13.4**	**13.5**	**14.5**
All 2	14.87						-	**0.1**	**0.9**	**1.3**	**3.3**	**3.4**	**3.7**	**4.3**	**6.1**	**6.4**	**6.8**	**7.2**	**9.2**	**9.3**	**9.5**	**9.8**	**11.6**	**11.7**	**12.7**
Norm 2	15.01							-	**0.7**	**1.2**	**3.2**	**3.2**	**3.5**	**4.2**	**6.0**	**6.3**	**6.7**	**7.0**	**9.0**	**9.1**	**9.3**	**9.6**	**11.4**	**11.6**	**12.6**
Real 2	15.76								-	**0.5**	**2.4**	**2.5**	**2.8**	**3.5**	**5.2**	**5.5**	**5.9**	**6.3**	**8.3**	**8.4**	**8.6**	**8.9**	**10.7**	**10.8**	**11.8**
Rehab 3	16.21									-	**2.0**	**2.0**	**2.3**	**3.0**	**4.8**	**5.1**	**5.5**	**5.8**	**7.8**	**8.0**	**8.1**	**8.4**	**10.3**	**10.4**	**11.4**
All 3	18.19										-	**0.1**	**0.3**	**1.0**	**2.8**	**3.1**	**3.5**	**3.9**	**5.9**	**6.0**	**6.2**	**6.4**	**8.3**	**8.4**	**9.4**
Real 3	18.24											-	**0.3**	**1.0**	**2.8**	**3.0**	**3.4**	**3.8**	**5.8**	**5.9**	**6.1**	**6.4**	**8.2**	**8.3**	**9.4**
Norm 3	18.52												-	**0.7**	**2.5**	**2.8**	**3.2**	**3.5**	**5.5**	**5.6**	**5.8**	**6.1**	**7.9**	**8.1**	**9.1**
Rehab 4	19.21													-	**1.8**	**2.1**	**2.5**	**2.8**	**4.8**	**4.9**	**5.1**	**5.4**	**7.2**	**7.4**	**8.4**
Real 4	20.99														-	**0.3**	**0.7**	**1.1**	**3.0**	**3.2**	**3.4**	**3.6**	**5.5**	**5.6**	**6.6**
All 4	21.29															-	**0.4**	**0.8**	**2.8**	**2.9**	**3.1**	**3.3**	**5.2**	**5.3**	**6.3**
Norm 4	21.69																-	**0.4**	**2.4**	**2.5**	**2.7**	**2.9**	**4.8**	**4.9**	**5.9**
Rehab 5	22.05																	-	**2.0**	**2.1**	**2.3**	**2.6**	**4.4**	**4.5**	**5.5**
All 5	24.04																		-	**0.1**	**0.3**	**0.6**	**2.4**	**2.5**	**3.5**
Real 5	24.16																			-	**0.2**	**0.5**	**2.3**	**2.4**	**3.4**
Norm 5	24.35																				-	**0.3**	**2.1**	**2.2**	**3.2**
Rehab 6	24.62																					-	**1.8**	**2.0**	**3.0**
All 6	26.46																						-	**0.1**	**1.1**
Norm 6	26.57																							-	**1.0**
Real 6	27.60																								-

Appendix E

(Submaximal test protocol and prediction of maximal oxygen consumption)

USER INSTRUCTIONS FOR A SUB-MAXIMAL STEP TEST FOR PEOPLE WITH LOW TOLERANCE TO EXERCISE.

Steve Selig, Cameron Gosling, Fiona Bowie, John Carlson.

Centre for Rehabilitation, Exercise and Sport Science, Victoria University

Funded by a grant-in-aid from the Commonwealth Rehabilitation Service

Informed Consent and Risk Factor Screening:

All clients must give their informed consent and be screened for risk factors prior to an appointment being made for an exercise test. An example of a screening form and the informed consent sheet are attached. *High risk individuals may be tested at Victoria University if certain conditions are met.*

Data entry: Enter the client's name, date, age, sex, weight and height on the "**frontsheet**" of the Excel test workbook:

Enter Data	Format for data entry	Example
Name		Fred Jones
Date	dd/mm/yr	12/2/96
Age	number only	43
Sex: 1 = male; 0 = female	0 or 1	1
Weight	accurate to first decimal	75.5
Height	accurate to nearest cm	181
Do not enter step height *	n/a	n/a
Do not enter predicted maximum heart rate *	n/a	n/a

* The desired step height and predicted maximum heart rate will be calculated and displayed. Do not attempt to calculate them as it will remove the formulae from the spreadsheet! Set the step bench to that height. Use the predicted maximum heart rate as a GUIDE ONLY to help measure the exertion level of the individual at each stage of the test. The main tool for exertion level is the Borg Rating of Perceived Exertion (attached).

Warm up:

Clients should undergo five minutes of light exercise (eg walking) to warm up. Connect up and check the equipment to be used for heart rate measurement. Follow this by one minute of familiarisation exercise on the step bench at the lowest step rate of 14 ascents per minute (ie metronome set at 4 x 14 = 56 beeps per minute).

Standard Instructions to Client:

See attached sheet.

Safety and Ethics:

Clients should exercise as long as they feel able. **There is no compulsion to exercise to the end of the six minute test.** The test will yield a valid and reliable result if the client is able to complete two minutes. For those that are not able to complete two minutes, it is assumed that their tolerance to exercise is low. If a client stops part of the way through a minute stage, then for the purposes of the test results, only those stages that are completed are counted. Try to encourage clients to exercise for as long as possible (up to 6 minutes) but **cease the test immediately** if any of the following criteria for stopping are evident:

(i) subject wishes to stop

(ii) subject experiences chest pain (typical of angina), severe shortness of breath or any other pain related to, or caused by, the exercise.

(iii) subject wishes to continue but there are abnormal signs of cardiorespiratory distress (eg facial pallor, cold sweat across the brow, lack of response to the supervisor's inquiries as to how they are feeling)

(iv) subject perceives that he/she is working "very hard" (ie he/she has reached 17 on the Borg Ratings of Perceived Exertion)

(v) subject has almost reached his/her predicted maximum heart rate (ie within 5 bpm of predicted HR_{peak})

Test:

A metronome (preferably electronic) is used to pace the steps: set the metronome to four times the required step rate (i.e. one beep for each of "UP-UP-DOWN-DOWN").

Stage = Time (minutes)	Metronome setting	Stepping frequency = the number of the following step cycles per minute: UP-UP-DOWN-DOWN
0 to 1	56	14
1 to 2	72	18
2 to 3	88	22
3 to 4	104	26
4 to 5	120	30
5 to 6	136	34

Data recording:

During each stage, the client must give a Borg Rating of Perceived Exertion (RPE) (at 40 seconds into the stage) and heart rate must be recorded (at the end of the minute). It is not necessary to record the RPE for the test results.

Cool down:

Continue to step on the spot for two minutes at 22 ascents per minute and a further two minutes at 14 steps per minute. Continue to monitor the client closely, using the same set of stopping criteria as for the main test.

Data entry (cont.) and reporting:

1. Select the appropriate worksheet according to the length of the test; i.e. "6 min", "5 min", "4 min" or "3 min or less".
2. Enter the client's heart rate responses for each minute (except the first minute which is not a reliable indicator of physiological effort).
3. For tests that last less than 3 min or less, go to step # 5.
4. Select "Tools" from the toolbar above. Select "Macro" from this menu. Select the appropriate macro according to the length of the test; i.e. "6 min", "5 min", "4 min". Run the macro. When a message appears that invites you to overwrite old data, respond with "OK".
5. Print the page.

Equipment:

- Step bench: standard height of, say 15 or 20 cm, with up to eight one cm plates to obtain the required height.
- Metronome: electronic with both visual (flashing light) and audible (beeps) signals.
- Heart rate monitor (Sports Tester or equivalent)
- Computer: IBM with MS Excel (Version 5 or later; also need analysis tools to perform linear regression). Printer on-line.
- Borg Ratings of Perceived Exertion (attached).
- Risk factor form (example attached).
- Informed consent (example attached).
- Bathroom Scales (calibrated to $\pm$ 0.5 kg).
- Method of measuring height to $\pm$ 1 cm.

Standard Instructions to Client:

Explain the test procedure to the client and answer any questions that they have:

"The test requires you to step up and down in time with the metronome for a maximum of 6 minutes. Keep in time with the beeps generated by the metronome ..... do not get ahead or behind the beeps. The test will start slowly. At the end of each minute the speed of stepping will increase; if you are still going at 6 minutes, you will be stepping quite fast. You may wish to stop the test before 6 minutes or before a full minute stage is completed. That is OK. To obtain an estimate of your fitness, you will need to step for at least 2 minutes. You should exercise as long as you feel able but stop if you feel any pain or become distressed. During the test, we will ask how you are feeling. *(show them the sheet of Borg Ratings of Perceived Exertion, attached).* Look at this table now which gives ratings of perceived physical exertion. During each one minute stage of the test, answer how you are feeling when asked, by pointing to the correct rating or calling the number".

Borg Ratings of Perceived Exertion (RPE)

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

Criteria for stopping of the test:

(i) subject wishes to stop

(ii) subject experiences chest pain (typical of angina), severe shortness of breath or any other pain related to, or caused by, the exercise.

(iii) subject wishes to continue but there are abnormal signs of cardiorespiratory distress (eg facial pallor, cold sweat across the brow, lack of response to the supervisor's inquiries as to how they are feeling)

(iv) subject perceives that he/she is working "very hard" (ie he/she has reached 17 on the Borg Ratings of Perceived Exertion)

(v) subject has almost reached his/her predicted maximum heart rate (ie within 5 bpm of predicted HR_{peak})

Name	
Date	
Age	
Sex: 1 = male; 0 = female	
Weight kg	
Height cm	
Step Height cm	
Predicted max HR	
Time	Heart Rate
1	
2	
3	
4	
5	
6	

Table of Normative Data

	STAGE reached	Oxygen equivalent VO_2 ml kg^{-1} min^{-1}	Work equivalent: as a percentage of rest
Excellent	6	26.5	8
Very Good	5	23.9	7
Good	4	21.2	6
Average	3	18.2	5
Fair	2	14.7	4
Needs Improvement	1	11.1	3

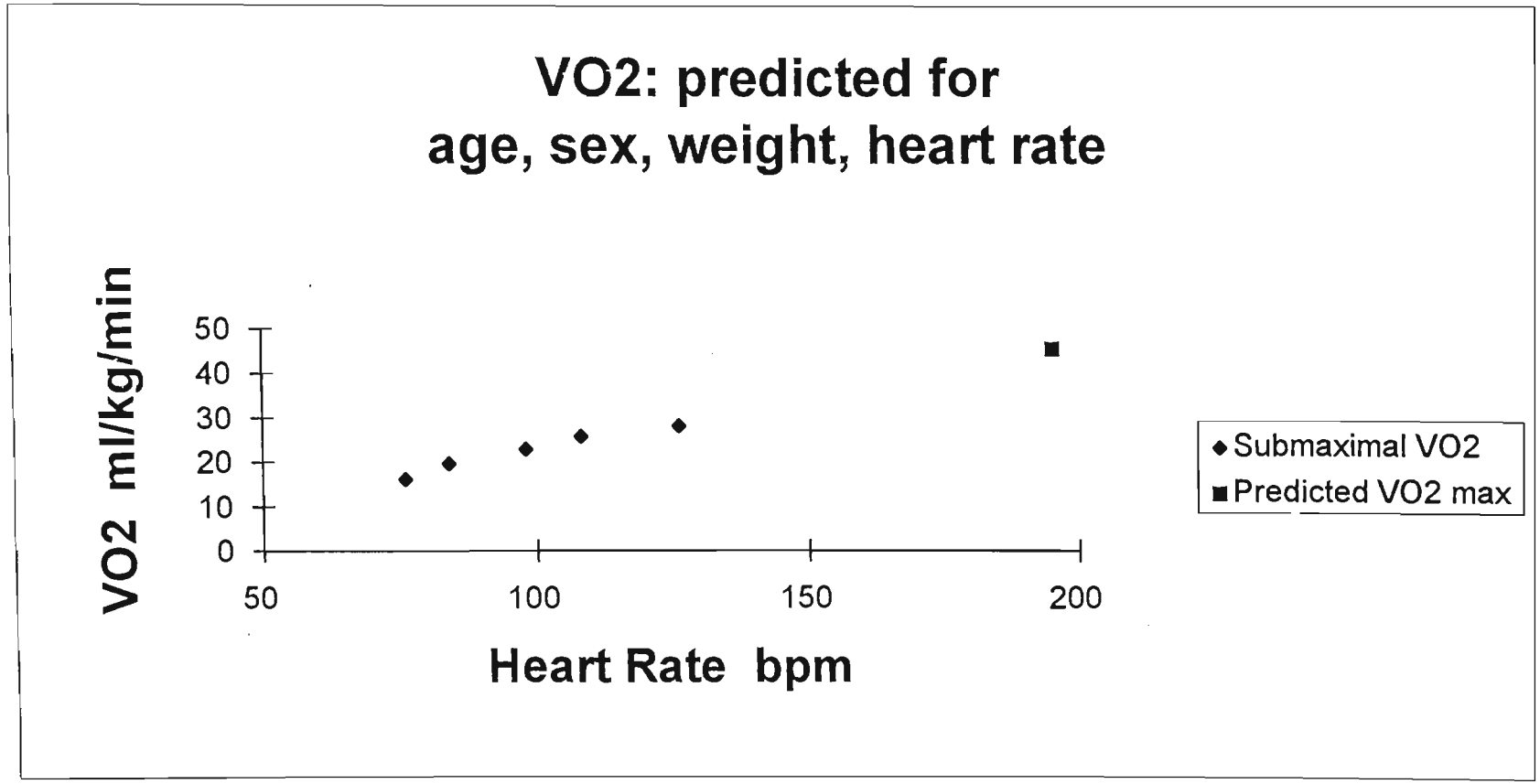
Appendix F

(Output of predicted maximal data for a normal, and a subject taking Beta blockers)

6 Min

Name	Subject B - blockers
Date	17-Mar-96
Age	25
Sex: 1 = male; 0 = female	1
Weight kg	70
Height cm	183
Step Height cm	23

Time	Heart Rate	Submaximal VO2
2	76	16.1
3	84	19.8
4	98	22.9
5	108	25.8
6	126	28.2
	Predicted max HR	Predicted VO2 max
	195	45.5



Regression coefficient 0.9801