2002

Validating the use of the shuttle walking test in healthy adult women

Micheal C.M. Lim
Edith Cowan University

VALIDATING THE USE OF THE SHUTTLE WALKING TEST IN HEALTHY ADULT WOMEN

By

Micheal C.M. Lim

Candidate for Bachelor of Science Honours (Sports Science)

A thesis submitted in partial fulfilment of the requirements for the award of

<u>Bachelor of Science Honours (Sports Science)</u>

Faculty of Communications, Health and Science

School of Biomedical and Sports Science

Edith Cowan University

Date of Submission: 11 November 2002

USE OF THESIS

ABSTRACT

The Shuttle Walking Test (SWT), with its externally paced characteristics, is commonly used as an objective measure of functional capacity. The reliability and validity of the SWT has been previously shown but only in patient populations. No studies have been carried out to investigate the validity of the SWT in healthy adult women. Therefore, the primary aim of this test was to determine if the SWT is a valid field measure of cardiorespiratory fitness in healthy adult women. A secondary aim was to identify if variables, such as age, body composition and habitual physical activity influence performance on the SWT.

The distance ambulated on the SWT was compared with a standard laboratory test of cardiorespiratory capacity, peak oxygen consumption ($\dot{V}O_{2peak}$) determined on an Individualised Balke Treadmill Test (IBT). Thirty-four healthy adult women with an age range of 32 - 65 yrs completed both exercise tests. Mean (± SD) SWT distance 624.5 (148.9) m and $\dot{V}O_{2peak}$ 29.4 (7.8) ml.kg^{-1}.min^{-1} were higher than that shown in previous studies of patient populations. Pearson product moment correlation analysis indicated a moderate but significant relationship ($r = 0.58$, $p = 0.0005$) between SWT distance and $\dot{V}O_{2peak}$. Variability in performance on the SWT can be explained partly by age and estimated body fat.

This study is the first to investigate the validity of the SWT in healthy adult women. The correlation with $\dot{V}O_{2peak}$ from IBT was lower than that in previous studies with patient populations. The findings suggest that performance on the SWT in healthy

adult women is limited by locomotor ability as well as cardiorespiratory fitness. Therefore, the use of SWT as a field measure of cardiorespiratory fitness in healthy adult women has limitations. The study provides the basis for further work to modify the SWT for use in a healthy adult population.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where the due reference is made in text; or

(iii) contain any defamatory material

Signature: __________________

Date: 11 November 2002

ACKNOWLEDGEMENTS

The successful completion of this study would not have been possible without the significant contribution/s from various people.

First of all, Dr. Paul Sacco, my chief supervisor for this study. A big thank you for all the guidance you have provided throughout this year. It has been an incredible experience learning from you the process of conducting and completing a quality research. I appreciate all the time you have spent on this project, especially during the "final assault" leading to this completed product. It has been a hectic week but it would not have been possible without all your quick turnovers for the initial drafts. For all your motivations and encouragements, I thank you!

To Peter Hope, my co-supervisor. Thanks for assisting in the development of this project as a whole. Specifically, huge thanks for the incredible amount of time spent in developing the macro for downloading the physical activity data from the activity monitor. You have made the task so much easier. You have also taken precious time out from your busy research schedule and family commitments to help with whatever you could. Thank you!

To Holly Fraser, for providing assistance during the data collection period. Your help has made the process easier and more efficient.

Special thanks to Dr Anna Timperio (Deakin University) for kindly loaning the 20 MTI activity monitors received through a grant from the Commonwealth Department of Health and Aged Care used in this study. Also, appreciation to Kristina Medigovich, from School of Nursing, for kindly allowing me to use some of her activity monitors when we had to return those due to DHA.

To all the academic staff in the School of Biomedical and Sports Science. The development of this thesis would not have been possible if not for all the skills acquired during the undergraduate years. It has been an incredible learning process over the past three years. Credit should be given to you for making it such an interesting and intirguing one. Thank you!

To the technical support staff, Mary and Nadija . Your technical expertise and contribution has assisted the completion of this study within the limited time span.

To Andrew Guilfoyle, for your assistance with the providing advice with statistical analysis.

To all other postgraduates, you have created a really conducive environment for research. Your support has helped making this year a hard but pleasant experience.

Most importantly, special thanks to my parents, without whom I would not have made the transition into a career in the field of exercise science. I can't thank you enough for all the emotional and financial support you have provided for me all these while. Your relentless support in my pursuit of a career I dream of has been incredible. I love you all and dedicate this work of mine to you.

To the person I cherish in life, Carol. The past year has been pretty tough but I guess we have the finishing line in sight now. Thanks for all the emotional support and understanding during those very stressful times.

To Luke Wheeler and Jean Ho, for taking your precious time out to proof read the thesis for me. Your contributions have made this product a much better one and I greatly appreciate it.

Last but not least, to Jimmy Beh and Aspalela. You have provided me with exceptional motivations and encouragements throughout the year. Thank you!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

A-P HR_{peak}	Age predicted peak heart rate
Est. BF	Estimated body fat
Est. FFM	Estimated fat free mass
HR_{peak}	Peak heart rate
IBT	Individualised Balke test
MTI-Total	Total habitual physical activity measured by activity monitor
MET	Metabolic equivalent
RPE-C	Central rating of perceived exertion
RPE-P	Peripheral rating of perceived exertion
SWT	Shuttle walking test
SpO_2	Oxygen saturation
$\dot{V}O_{2peak}$	Peak oxygen consumption
$\dot{V}O_2$	Oxygen consumption
$\dot{V}O_{2max}$	Maximal oxygen consumption
7DR-Total	Total habitual physical activity measured by seven- day recall interview
% A-P HR_{peak}	Percentage of age predicted peak heart rate

CHAPTER 1

INTRODUCTION

1.1 Background of study

For many decades, cardiopulmonary exercise testing has withstood numerous technological changes to remain the most widely used, objective measure of exercise performance. Peak oxygen consumption ($\dot{V}O_{2peak}$) is often used as an index for cardiorespiratory fitness or functional capacity. Numerous studies have demonstrated a strong negative association between $\dot{V}O_{2peak}$ and risk of mortality associated with common epidemiological diseases (Blair et al., 1996; Haddock, Hopp, Mason, Blix, & Blair, 1998; Lakka et al., 1994; LaMonte et al., 2000; McMurray, Ainsworth, Harrell, Griggs, & Williams, 1998).

Exercise testing with respiratory gas exchange analysis can be quite intimidating to subjects and requires expensive, sophisticated equipment and trained personnel (Pina et al., 1995; Singh, 1992). Since the development of the 12 min walking test by McGavin, Gupta, and McHardy (1976), field measures of functional capacity have gained popularity because of their ease of administration and ability to reflect an individual's daily activities (Ambrosino, 1999; Steele, 1996). A recent review by Solway, Brooks, Lacasse and Thomas (2001) revealed six different types of functional walking tests commonly used, including 2-min walk test, 6-min walk test, 12-min walk test, self-paced walk test and the shuttle walk test.

Recently, the shuttle walk test (SWT), with its externally paced nature, has become popular amongst clinician for both evaluation of exercise capacity (Green, Watts, Rankin, Wong, & O' Driscoll, 2001; Lewis, Newall, Townend, Hill, & Bonser, 2001; Morales, Montemayor, & Martinez, 2000) and setting of exercise intensity for rehabilitation programmes (Green, Singh, Williams, & Morgan, 2001; Hernandez et al., 2000; Singh, Smith, Hyland, & Morgan, 1998; Singh, Sodergren, Hyland, Williams, & Morgan, 2001). The SWT has been shown to be a safe, reliable and valid measure of functional capacity (Booth & Adams, 2001; Dyer, Singh, Stockley, Sinclair, & Hill, 2002; D. J. Green et al., 2001; Morales et al., 1999; Singh, Morgan, Hardman, Rowe, & Bardsley, 1994).

Studies comparing performance on the SWT and $\dot{V}O_{2peak}$ have been limited to patient populations, for example patients with chronic heart disease, chronic airway obstruction, rheumatoid arthritis and fibromyalgia (Macsween, Johnson, Armstrong, & Bonn, 2001; Morales et al., 1999; Pankoff, Hobby, Lucy, & Overend, 2002; Singh et al., 1994). A review of the literature has revealed only one published study on healthy population (Webb, Lawrence, Jones, Singh, & Morgan, 2002) and none so far with women.

1.2 Purpose of the Study

The main purpose of this study was to determine the validity of the SWT as a field measure of cardiorespiratory fitness in healthy adult women. The secondary purpose was to identify how variables known to affect functional capacity such as age, body composition and physical activity, influence performance on the SWT.

1.3 Significance of the Study

Provide information on whether the SWT is a valid field measure of cardiorespiratory fitness in the normal population. If shown to be valid, it would provide clinicians in the medical, epidemiological and health promotion settings with a cost effective and easy to administer alternative to cardiopulmonary exercise testing in adult women.

Results from this study may serve as useful control information for future research in patient populations. Being able to understand the relationship on a healthy adult will simplify the data interpretation for specific patient population.

1.4 Research Questions

To achieve the purpose and guide the study, two key research questions were developed: -

1. Is the SWT a valid measure of cardiorespiratory fitness (functional capacity)?
2. Do individual characteristics such as age, body composition and levels of habitual physical activity influence performance on the SWT?

1.5 Research hypothesis

In order to predict the direction for the research study, the following hypotheses were developed: -

1. There would be a significant positive correlation between and performance on the SWT and $\dot{V}O_{2peak}$ obtained from a standard walking exercise test.
2. Age, body composition and level of habitual physical activity will be related to performance of the SWT.

1.6 Assumptions

The following assumptions were made for the study: -

1. The sample drawn for this study was representative of adult women in Western Australia
2. Subjects performed to their highest abilities and gave accurate answers to measures obtained (e.g. rating of perceived exertion) during both exercise tests.
3. Subjects recalled their habitual physical activities to their best abilities.
4. Subjects did not alter activities during the assessment period so that that the activities recorded during the study period accurately reflect the habitual pattern of physical activity.

1.7 Delimitations

The following delimitations set the boundaries for this study: -

1. The target sample included only subjects who responded to the recruitment drive. This group may be more motivated than others to participate in physical activity.
2. The geographical limits set for this study (i.e. northern suburbs of Perth metropolitan area) may not reflect the general adult women population in Perth, Western Australia.
3. Only women aged 32 – 65 yrs were recruited for this study.
4. Subjects were excluded if they were suffering from any major cardiorespiratory and/or musculoskeletal problems that were contraindications to exercise testing.

CHAPTER 2

LITERATURE REVIEW

The first part of this chapter sets out to provide a detailed review of the exercise tests used for the study. The second part of the review identifies how variables such as age, body composition and physical activity may influence an individual's functional capacity.

2.1 Cardiopulmonary exercise testing

The upper limit of cardio-respiratory function, more commonly known as the maximal exercise/ functional capacity, is characterised by an individual's ability to sustain maximal work (Hartung, Blancq, Lally, & Krock, 1995; Myers & Froelicher, 1990). Physiologically, this is the most important indicator of cardiorespiratory fitness (Holly & Shaffrath, 2001, p.450) and can be measured by determining the rate of maximum transport and use of oxygen ($\dot{V}O_{2max}$) within the body. For the purpose of this study, the term $\dot{V}O_{2max}$ and/ or its associated test may be inappropriate. Depending on a number of factors such as motivation, subjects may not be able to perform maximal exercise to voluntary exhaustion so as to achieve $\dot{V}O_{2max}$. Hence, peak oxygen consumption ($\dot{V}O_{2peak}$), defined by Wasserman, Hansen, Sue, Casaburi and Whipp (1999, p.65) as the "highest $\dot{V}O_2$ achieved for a presumed maximal exercise effort", will be used.

$\dot{V}O_{2peak}$ is measured using graded incremental exercise testing. Under controlled situations, the exercise test is able to quantify and distinguish an individual's functional limitation to dynamic work (Myers & Madhavan, 2001; Pina et al., 1995). Due primarily to its intrinsic ability to provide vital diagnostic and prognostic information, this non- invasive procedure has become popular amongst clinicians (Gibbons et al., 1997; Pina et al., 1995).

Such tests have often been classified as the "gold standard" in evaluating cardio-respiratory fitness and are commonly conducted with a treadmill or cycle ergometer using a symptom- limited graded exercise protocol. As this study sought to validate the SWT with cardio-respiratory fitness, walking has been selected as the prime mode of locomotion. It is one of the most common locomotive skills that are familiar with most individuals. For these reasons, only studies that performed exercise tests using a walking treadmill protocol were reviewed.

2.1.1 Selection of ideal protocol for laboratory test: Ramp or step

Graded increments during the exercise test can be performed either by increasing the work rate continuously (Ramp protocol) or by a uniform amount at regular time intervals (Step protocol). Balke (1959) and Bruce (1963), cited in Froelicher et al. (1974) were two pioneers in the development of step exercise protocols to evaluate physical fitness and cardiovascular function respectively. The Bruce protocol remains the most commonly used procedure (Balady et al., 2000, p.97). Froelicher et al. (1974) and Froelicher, Thompson, Davis, Stewart and Triebwasser (1975) conducted studies to compare three (Bruce, Balke and Taylor) and two (Bruce and Balke) maximal treadmill exercise protocols respectively. Peak heart rate (HR_{peak})

responses were similar with both studies- displaying no significant differences between the protocols. $\dot{V}O_{2peak}$ was found to be reproducible for the three protocols (Froelicher et al., 1974). However, the mean $\dot{V}O_{2peak}$ was found to be significantly higher in moderately active subjects who undertook the Bruce protocol (Froelicher et al., 1975). Working with healthy women population, Pollock et al. (1982) also found $\dot{V}O_{2peak}$ to be higher with the Bruce protocol. The differences may have been the result of a smaller sample group (n=15) used in the study. With a much larger sample size (Balke, n=79; Bruce, n=77), Froelicher et al. (1975) concluded that $\dot{V}O_{2peak}$ varies widely between individuals, thus supporting the earlier view of the need for an increased sample size to obtain a more accurate analysis for comparison. In addition, the difference in experimental design (i.e. same day test for Bruce and Balke) and one protocol each week in the study by Froelicher et al. (1974) might have resulted in the difference in results.

Levine (2001, p.10) suggested that one of the requirement of exercise testing is the "ability to distinguish 1 metabolic equivalent (METs) increment in functional capacity". The Bruce protocol, mentioned earlier does not conform to this requirement. One test method that avoids this is the ramp protocol, which is less intimidating due to the gradual increases in work rate. More importantly, the work rate changes can be individualised to suit specific patient characteristics (Bader, Maguire, & Balady, 1999; Myers et al., 1992; Myers & Froelicher, 1990). Reviewing ramp protocol, Myers et al. (1992) suggested that changes in $\dot{V}O_2$ with work rate did not differ at high or low intensity with healthy individuals. Also, the authors found the ramp protocol to be more accurate over step protocols in predicting $\dot{V}O_{2max}$.

Recently, several studies have compared the ramp and step protocols such as Bruce and Balke. In their work with obese women and the aged (>60 yrs) respectively, Bader, Maguire and Balady (1999) and McInnis, Bader, Pierce and Balady (1999) administered a pre-test activity questionnaire to all their subjects and determined an estimate of the peak MET capacity. The intensity of the ramp protocol selected (eg. Very low ramp = 4.7 MET, Low ramp = 7.0 MET) was based on the estimated peak capacity obtained from the questionnaire. The protocol was structured so as to meet the required intensity in 10 minutes. The results showed that when each subject's functional capacity was individualised based on a pre-test activity questionnaire, cardiopulmonary responses were similar, between step and ramp protocols. However, the accuracy of questionnaires to accurately discriminate an estimate of peak capacity in healthy adult women remains a question. The authors in the above study have also used women who were obese or patients with coronary disease who have a smaller range of $\dot{V}O_{2peak}$ than most healthy individuals. With a wider range of cardiorespiratory fitness, the use of such questionnaires may lead to larger increments in workload thereby creating a potential for over estimation of $\dot{V}O_{2peak}$. The use of a questionnaire to estimate peak cardiopulmonary response may seem a logical idea but for the reasons previously mentioned would not be used for this study. Nonetheless, the ramp protocol still remains the clear choice as a mode of exercise testing.

Previous studies have demonstrated a decline in walking speed with age in healthy individuals (Bohannon, 1997; Cunningham, Rechnitzer, Pearce, & Donner, 1982; Himann, Cunningham, Rechnitzer, & Paterson, 1988). Individual characteristics, such as height, weight, body fat and muscle strength, were also shown to be related to walking speeds. Cunningham et al. (1982) investigated an additional covariate in

$\dot{V}O_{2peak}$ and found that $\dot{V}O_{2peak}$ exerts a significant relationship to all self- selected walking speeds.

It seems logical from the review that if a standard walking speed was used in an exercise test, subjects with lower $\dot{V}O_{2peak}$ may be working at a higher proportion of their maximal capacity. Hence, there remains a possibility for fatigue not due to them reaching their full cardiorespiratory potential. Therefore, it was decided that an individualised Balke protocol, based on subject's selection of her own walking speed, would be used for the study. This selection meets both criteria of small increments and individualised protocol.

2.1.2 Functional walking tests

With the mode of exercise more closely reflecting daily activities, walking tests have been proven to be easy to administer and provide a better measure of functional capacity than cycle or arm exercises (D. J. Green et al., 2001; Payne & Skehan, 1996; Steele, 1996). As mentioned earlier, functional walking tests can be divided into two main categories: Self-paced (2-minute walking test, 6-minute walking test, 12-minute walking test and self-paced walking test) and externally paced (Shuttle Walking Test (SWT)) (Solway et al., 2001).

Many researchers have questioned the use of self-paced walking tests, namely the 6 and 12 minute walking test. Previous studies have shown both these walking tests to be a valid measure of functional capacity in patient populations (Baarends, Schols, Mostert, Janssen, & Wouters, 1998; Tallaj et al., 2001). However, with the self paced nature of these tests, the distance ambulated can be varied. Troosters, Gosselink and

Decramer (1999) evaluated the 6-minute walking test on healthy elderly subjects. They found that a wide range in the distance ambulated and explained that as due to characteristics such as height, age, gender and weight. Moreover, based on a review by Sadaria and Bohannon (2001), it was documented that performance of the these self-paced walking tests are often conducted on different courses with different shapes and lengths. As suggested by Gibbons, Fruchter, Sloan and Levy (2001), these features resulted in the different frequency of directional changes thus creating a wide range in the distance ambulated. Most importantly, the self paced nature of the 6 or 12 minute walking tests could possibly create a potential psychological source of variance. Guyatt et al. (1984) investigated the effect of encouragement on the effect of such self- paced walking tests. They found that simple encouragement given during the test provided significant improvements in the distance ambulated. They recommended that if encouragement was given, it should be rigorously standardised, in terms of level of encouragements and intervals the encouragements are administered. Thus, it is clearly shown that the self- paced walking tests can be influenced by external factors that would subsequently affect the performance and would not be recommended as an appropriate study tool. In addition, the inconsistent study design used in previous studies creates a potential for the implications of data interpretations, in different or even similar subject populations.

Acknowledging such limitations with the self- paced walking test, Singh, Morgan, Scott, Walters and Hardman (1992) proposed a test that is incremental and progressive so that functional capacity can be more accurately assessed. The Shuttle Walk Test (SWT) requires subjects to walk up and down a 10 metre course with the speed dictated by an audio signal (Payne & Skehan, 1996; Singh et al., 1992). Being standardised, it allows for direct comparison of different individual's performance.

More importantly, the external pacing using the standard audio signal reduces operational bias and hence allows a more direct and objective comparison of results (Payne & Skehan, 1996; Singh, 1992; Singh et al., 1992).

Studies have demonstrated the reproducibility of the SWT in patients with chronic heart failure (D. J. Green et al., 2001; Morales et al., 1999), chronic airway limitation (Dyer et al., 2002), spinal stenosis (Pratt, Fairbank, & Virr, 2002), advanced cancer (Booth & Adams, 2001) and fibromyalgia (Pankoff et al., 2002).

Studies by Casas et al. (2002) and D.J.Green et al. (2001) showed a similar incremental response with $\dot{V}O_{2peak}$ on a conventional laboratory exercise test and the SWT as compared with 6-minute walking tests. At peak intensity, cardiovascular response and $\dot{V}O_{2peak}$ were not significantly different between the SWT and treadmill test. In addition, D.J. Green et al. (2001) showed that peak heart rate responses were much higher than that observed in the 6-minute walking test. Singh et al. (1994) investigated the relationship between performance on the SWT and $\dot{V}O_{2peak}$ achieved during a conventional treadmill test. They found that SWT performance (in terms of distance ambulated) allows for prediction of $\dot{V}O_{2peak}$. Similar results were also demonstrated in patients with chronic heart failure (D. J. Green et al., 2001; Morales et al., 1999). All the aforementioned studies concluded that the SWT provides an adequate stimulus to elicit maximal values and hence is a valid exercise test with clinical populations. In general, even though most subjects had problems with the *turning* and accuracy in pacing, the SWT was better tolerated than the treadmill test for cardio-respiratory fitness (Keell, Chambers, Francis, Edwards, & Stables, 1998).

The only published study evaluating the use of the SWT in a normal healthy population investigated the relationship between SWT distance and age, physical activity and respiratory measures (Webb et al., 2002). It should be noted that no comparison was made with $\dot{V}O_{2peak}$ in the study and their results showed that forced expiratory volume (1 sec) was the only variable related to distance walked on the SWT. Although the studies described thus far have shown the SWT to be an accurate measure of functional capacity in patient populations, it remains unclear if this test is valid with healthy, adult women.

2.1.3 Limitations to performance of SWT

The main purpose of exercise tests is to provoke symptom limited maximal cardiorespiratory response from an individual. Studies reviewed above have been conducted primarily with patient populations, whom "in the presence of cardiorespiratory disorders, impairments in ventilatory, gas exchange, and circulatory processes restrict the aerobic capacity of exercising muscle and are frequently considered to limit exercise performance when finite boundaries of these processes are reached" (Hamilton, Killian, Summers, & Jones, 1996, p.1255). The understanding of such symptom limitations, which are often lower than that in healthy individuals, can be crucial in understanding the reason/s for termination of an exercise test.

Revill, Reynolds, Drummond, Noor and Ward (2002) investigated the symptom limitations during SWT in patients with chronic obstructive pulmonary disease and found that breathlessness was the primary limiting symptom in both conditions. Similar symptoms were also presented in previous study that have used the SWT (Dyer et al., 2002; Singh et al., 1992). Macsween et al. (2001) showed that only half of their

rheumatoid arthritis patients and 40% of their cardiac patients displayed breathlessness as the main symptom limitation to exercise test. It shows that the SWT is even able to exert similar symptom limitation, though not often in patients with musculoskeletal disease. With the cardiac patients, a reason for the fewer occurrences of breathlessness as a symptom limitation could be due to the stable conditions of the subjects.

Dyer et al. (2002) recruited age matched controls for their study in patients with chronic airway limitation. The healthy individuals did not present breathlessness as a symptom limitation, but instead, stopped the test due to inability to match the required speed on the test. This suggests that the symptom limitations experienced during a SWT in healthy individuals may be associated with muscular ability, rather than aerobic ability.

In their investigation on walking speeds, Bohannon (1997) found that the maximal walking speed of an individual can be influenced by muscle action strength. Troosters et al. (1999) evaluated the 6- minute walking test and found significant contribution of weight, in addition to age, height and sex, to walking distance. Although the latter study used different walking tests, it could be hypothesise that the ability of an individual to move, in relation to body composition, is crucial in the performance of the SWT.

As mentioned earlier, the use of the SWT reduced the possible variations due to the associated psychological impact of self- pacing and encouragements. With the external pacing, subjects would be "motivated" to keep up with the required pace. Kallinen, Suominen, Vuolteenaho and Alen (1998) provided evidence that effort

tolerance in elderly women is not only a factor of medical reasons, but also can be influenced by the activity level. A similar argument for the SWT can also be deiived from this study. The ability to tolerate a higher effort would result in the ability to achieve a higher level on the SWT. Hence, the performance on the SWT in healthy individuals could be influenced by this psychological factor.

2.2 Variables influencing functional capacity

2.2.1 Age and functional capacity

Age related decline in $\dot{V}O_{2peak}$ has also been well documented in the literature since the early 1970s (Drinkwater, Horvath, & Wells, 1975; Hossack & Bruce, 1982; Jackson et al., 1996; Ogawa et al., 1992; Profant et al., 1972; Tanaka, Monahan, & Seals, 2001; Wells, Boorman, & Riggs, 1992). The rate of decline in $\dot{V}O_{2peak}$ with age adopts a curvilinear response ranging from 0.27 to 0.54 $ml.kg^{-1}.min^{-1}.year^{-1}$ (Buskirk & Hodgson, 1987; Jackson et al., 1996; Talbot, Metter, & Fleg, 2000; Wells et al., 1992), with a greater decline occurring after age 40 yrs (Profant et al., 1972), 50 yrs (Drinkwater et al., 1975) and age 60 yrs (Buskirk & Hodgson, 1987). An example of the curvilinear decline is shown in Figure 1.

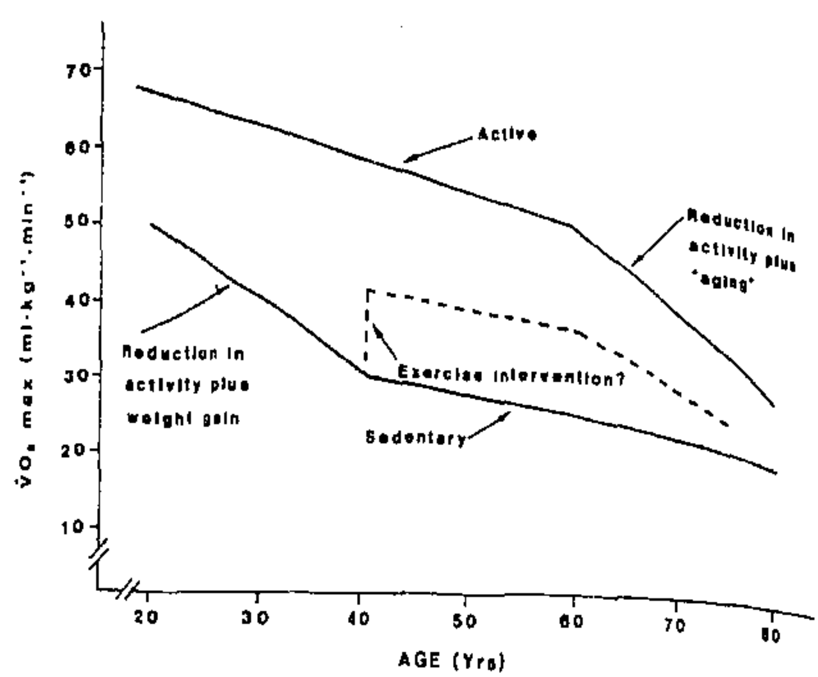


Figure 1. **Illustration showing age-related curvilinear decline in $\dot{V}O_{2peak}$ with advancing age (Buskirk & Hodgson, 1987)**

Figure 1 shows that older subjects, especially those ≥ 60 yrs, will present with a much lower functional capacity as compared to their younger counterparts (≤ 40 yrs). This demonstrated the discriminatory power of age on cardiorespiratory fitness in active individuals.

It was also observed that the $\dot{V}O_{2peak}$ attained by sedentary individuals are much lower than their active counterparts (Figure 1). Physical activity was one of the variables hypothesised to influence the SWT. In depth analysis of physical activity on $\dot{V}O_{2peak}$ will be provided later in this review. Nevertheless, the differences in the rate and the critical age of accelerated decline shown earlier need to be interpreted with caution due to the study design (cross-sectional vs. longitudinal), age group differentiation and/ or subject characteristics (trained vs. untrained).

In line with changes in $\dot{V}O_{2peak}$, studies by Tanaka, Monahan and Seals (2001) and Ogawa et al. (1992) have also demonstrated that maximal heart rate decreased with advancing age, with the latter showing no differences in the rate of decline between gender and physical activity.

2.2.2 Body composition and functional capacity

For the purpose of this review, body composition was defined as measures of body mass, estimated body fat (Est. BF) and estimated fat free mass (Est. FFM). As described in the previous section, a decline in $\dot{V}O_{2peak}$ can be observed with advancing age. However, it should be noted that body composition could also play a significant role in these observed rates of decline.

Fleg and Lakatta (1988), using urinary creatinine excretion as an index for muscle mass, observed a decline in $\dot{V}O_{2peak}$ and muscle mass with age. When $\dot{V}O_{2peak}$ was expressed relative to muscle mass, the decline was still significant with age. With a change of nearly 97% in the rate of decline (from –0.25 $ml.kg^{-1}.min^{-1}.year^{-1}$ to - 0.007 $ml.kg^{-1}FFM.min^{-1}.year^{-1}$), FFM was shown to attenuate the effect of age on $\dot{V}O_{2peak}$. Although a study by Toth, Gardner, Ades and Poehlman (1994) demonstrated similar relation between $\dot{V}O_{2peak}$ and FFM, the 28% change in rate of decline (from –0.028 $L.min^{-1}.year^{-1}$ to -0.02 $L.min^{-1}.year^{-1}$) was not as pronounced as shown earlier in the work of Fleg and Lakatta (1988). It was suggested that the marked difference in change in rate of decline in both studies was due to the expression of $\dot{V}O_{2peak}$ used in both studies. The use of body mass to normalise $\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$) (Fleg & Lakatta, 1988) instead of absolute $\dot{V}O_{2peak}$ ($L.min^{-1}$) (Toth et al., 1994), could have implications to the interpretation of both findings. The inclusion of body mass in the normalised equation could be inaccurate as this variable has previously been shown to increase the difference in $\dot{V}O_{2peak}$ with advancing age (Ogawa et al., 1992; Profant et al., 1972). In addition, Tanaka et al. (1997) demonstrated that the change in body mass with advancing age was not consistent, with an increase observed in sedentary but not endurance trained women.

Besides fat free mass, body composition also relates to the amount of fat in the body, expressed either as percent body fat or fat mass (Ogawa et al., 1992; Tanaka et al., 1997; Toth et al., 1994). Percent body weight was found to be higher in older subjects (~ $\geq$ 50yrs) (Ogawa et al., 1992; Tanaka et al., 1997) and was significantly related to $\dot{V}O_{2peak}$ (Toth et al., 1994). Toth et al. (1994) expressed $\dot{V}O_{2peak}$ result in terms of fat mass and showed a contribution of nearly 67% decrease in the rate of

decline with age (-0.028 $L.min^{-1}.year^{-1}$ to -0.009 $L.min^{-1}.year^{-1}$). These suggest that age associated lower $\dot{V}O_{2peak}$ in older subjects would be reduced further if the individual has a higher percent body fat. Thus, percent body fat can supersede the effect of age on $\dot{V}O_{2peak}$.

2.2.3 Habitual physical activity and functional capacity

Subjects with higher physical activity level tend to have higher cardiorespiratory fitness (Berthouze et al., 1995; Buskirk & Hodgson, 1987; Ogawa et al., 1992; Toth et al., 1994) (Figure 1). McMurray, Ainsworth, Harrell, Griggs and William (1998) and Talbot, Metter and Fleg (2000) classified habitual physical activity into three different categories (low, moderate and high). They found $\dot{V}O_{2peak}$ to be different in subjects, notably between the amount of time spent in low and high intensity. Subjects who participated in increased amount of high intensity physical activity was shown to have higher levels of $\dot{V}O_{2peak}$.

Interestingly, the reduction of habitual physical activity with age (Talbot et al., 2000) was not reflected with similar decline in $\dot{V}O_{2peak}$. As mentioned above, the investigators identified that it is the time spent at a specific intensity (high) of physical activity that influenced $\dot{V}O_{2peak}$ more than overall energy expenditure. Fitzgerald, Tanaka, Tran and Seals (1997) conducted a meta analysis to evaluate the decline of $\dot{V}O_{2peak}$ in women. They found that the rate of decline was lower in sedentary women, which they defined as not performing any form of aerobic exercise. These results were supported in another study conducted by Tanaka et al. (1997). Huang et al. (1998) investigated physical activity, functional limitation and physical fitness and

demonstrated a strong association between the three variables. Thus, it clearly demonstrated the effect of physical activity on the $\dot{V}O_{2peak}$. In fact, as the author suggested, "the association of physical fitness with functional limitation was so strong that it partly counteracted the relation of age to physical function" (Huang et al., 1998, p.1422).

In their study, Fitzgerald et al. (1997, p.164) commented that "individuals with highest level of $\dot{V}O_{2max}$ as young adults should demonstrate the greatest decline with advancing age". The investigators suggested this "baseline effect" to have an effect on the age associated changes in $\dot{V}O_{2peak}$. Subsequently, they expressed $\dot{V}O_{2peak}$ as percent change from a mean age of 25 yrs and found that the decline was similar in sedentary and active individuals. From these, it was acknowledged that genetic and prior physical activity could contribute to a higher $\dot{V}O_{2peak}$. Nevertheless, the limitation of this current cross-sectional design to accommodate the two variables was acknowledged.

2.3 Summary

In summary, the SWT has been shown to be a valid and reliable test of patient populations, however, the validity of this test in healthy adult women remains questionable. $\dot{V}O_{2peak}$, measured as an index of functional capacity, can be influenced by a myriad of factors. The factors identified in this review are age, body composition and habitual physical activity. These variables can work individually but are commonly linked to one another in their influence on $\dot{V}O_{2peak}$. Due mainly to the limited work on healthy adult women, the influence of these variables on performance on the SWT remains unclear.

CHAPTER 3

MATERIALS AND METHODS

3.1 Sample

Thirty-seven women (32- 65 yrs) were recruited from the northern suburbs of the Perth Metropolitan area. The Faculty of Communications, Health and Science Ethics sub- committee approved both the study design and recruitment procedure. Recruitment flyers were placed within Edith Cowan University (Joondalup Campus). With the support from the University Public Relations department, a brief article with details of the study was also placed in the staff newsletter (ECU Gazette) and in order to reach the wider community, a similar article/ recruitment advertisement was placed in 5 major local community newspapers in the northern suburbs of the Perth metropolitan area.

Respondents to the recruitment were invited to attend an initial session at the Exercise Physiology laboratory in Edith Cowan University (ECU). They read and signed an approved written informed consent and medical history questionnaire (Appendix A and B). Measurements of weight, height and body composition of participants were determined. Body mass and height were measured using an electronic scale and stadiometer respectively. Skinfolds were measured using a Harpenden® Skinfold calliper to provide an indicator for body composition. Measurements from four sites- biceps, triceps, subscapular and supraspinale were obtained. Three measurements were taken at each skinfold site with mean values obtained. A sum of the mean values at

the four sites was calculated and estimated percentage body fat (Est. BF) was determined from a normative table set out by Durnin and Wormsley (1974) cited in Egger, Champion, & Bolton (1998). Estimated fat free mass (Est. FFM), expressed in kilograms, was calculated using the Equation 1 below:

$$Est.\ FFM\ (kg) = Body\ mass\ (kg) - \left(\frac{Est.\ BF\ (\%)}{100} * body\ mass\ (kg) \right) \quad (1)$$

In accordance with guidelines set out by the American College of Sports Medicine (Balady et al., 2000) for exercise testing, a doctor from the medical suite within the university conducted a medical examination on all participants. To aid with the examination, an information sheet (Appendix C) with details of the tests was provided for the doctor. Participants were excluded from the study if they present with any of the following adverse medical conditions such as major cardiac/ respiratory problems, musculoskeletal injuries/ diseases. No subjects were excluded due to any of the aforementioned medical conditions.

Amongst the 37 who were initially recruited, three subjects did not complete the entire study due to time commitments and were excluded from the analysis. The characteristics (Mean ± SD) of the 34 participants are as follows- Age: 50.2 ± 11.1 (Range: 32 to 65 yrs); Height: 1.63 ± 0.1m; Weight: 64.5 ± 10.1 kg; Est. BF: 34.6 ± 8.3 %; Est. FFM: 41.7 ± 6.4 kg.

3.2 Study design

To evaluate the validity of the Shuttle Walking Test (SWT), a single measure correlation study comparing distance ambulated on SWT and $\dot{V}O_{2peak}$ on treadmill exercise test was used.

Participants attended the Exercise Physiology laboratory in ECU Joondalup campus son three separate occasions, with the first two sessions 7 days apart and the last session 8 days after the second. The longer time frame for the final session was to allow sufficient time to collect activity monitor data.

The first session was mainly the carrying out of administrative procedures and was described in the previous section. During the second session, participants were randomly assigned to either one of two exercise tests- Shuttle Walking Test (SWT) or Individualised Balke Test (IBT). They were provided with instructions and details of the tests as described in the following section. Following which, participants were briefed and instructed in the use of the activity monitor. Participants returned eight days later for the final session. They returned the activity monitor and performed the other exercise test- being either the IBT or SWT. The experimenter administered the Seven Day Recall (7DR) at the end of all three sessions in order to ensure the final recall reflects that of the individual's habitual activity pattern.

3.3 Procedure

3.3.1 Individualised Balke Test (IBT)

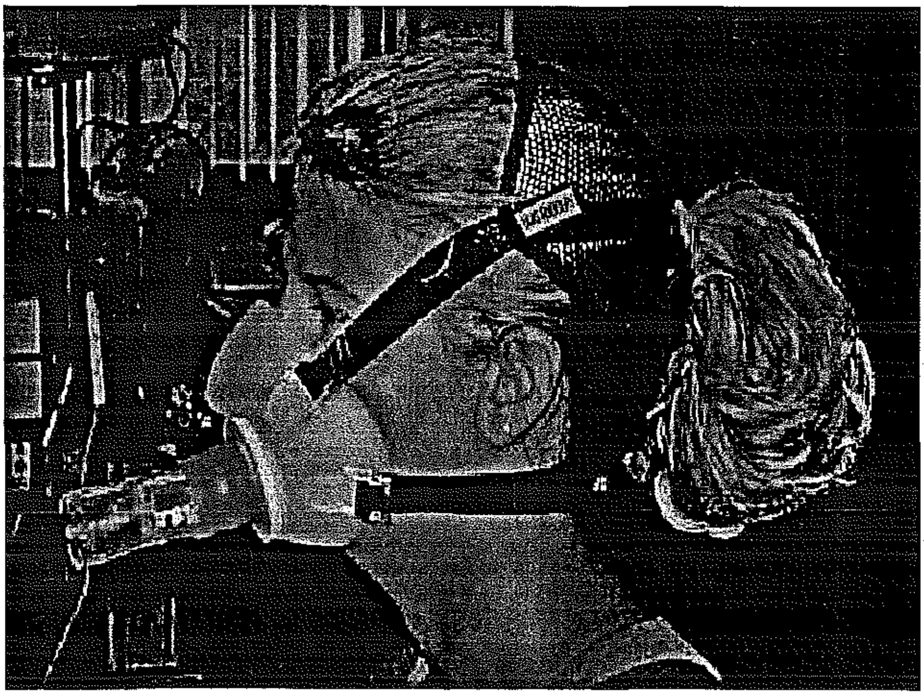
Peak oxygen consumption ($\dot{V}O_{2peak}$), an indicator of cardio-respiratory fitness, was measured using the Individualised Balke Test (IBT). The IBT was adapted from the original protocol developed by Balke (1959) cited in Froelicher et al. (1975). Participants walked at a constant speed (3.0 ± 0.1 mph, Range: 2.1 to 4 mph) on a Trackmaster® TM500 Treadmill ergometer, with the gradient increasing every one-minute after the first stage (Table 1).

Standard instructions were provided to help subjects select their own comfortable speed before the test began. During the test, participants were given strong verbal encouragements to ensure they exercised to the highest ability. The test was terminated when the subjects could no longer continue. A three-minute cool-down at a comfortable pace at 0% gradient was performed by all subjects. Heart rate was checked to ensure it approximated resting level before subjects were allowed to leave.

Table 1. <u>Protocol for Individualised Balke Test (IBT)</u>

Stage	Time (mins)	Speed (mph)	Gradient (%)
1	2:00	Speed selected based on individual's preference	0
2	1:00		1
3	1:00		2
4	1:00		3
5	1:00		4
6	1:00		5
7	1:00		6
8	1:00		7
9	1:00		8
10	1:00		9
11	1:00		10
12	1:00		11
13	1:00		12
14	1:00		13
15	1:00		14
Recovery			
R1	1:00		0
R2	1:00		0
R3	1:00		0

Respiratory gas exchange analysis was also conducted using the MedGraphics® CPX/D™ system with BreezEx™ programme. Subjects were fitted with an appropriate size Hans Rudolph® Two-way Non-Rebreathing Respiratory face masks (Hans Rudolph Inc., USA) with preVent pneumotach (Medgraphics® Corp., USA) attached to the front of the facemask (Figure 2). A check was conducted prior to each test to ensure an airtight seal around the mask.



<u>Figure 2.</u> Setup of face mask for Individualised Balke Test

Calibration of the MedGraphics® CPX/D™ gas analyser and pneumotach was conducted before each test, using guidelines set out by the manufacturer. To correct for environmental (room air) differences, barometric pressure, room temperature and relative humidity were measured. Calibration of the flow through the pneumotach at varying velocities was performed using a 3-Litre calibration syringe (Medgrahics® Corp., USA). The reference gas was calibrated with a known beta grade gas mixture (15.3 % O_2, 4.1% CO_2, BOC gases, Australia).

Breath- by breath results were downloaded to a Microsoft® Excel spreadsheet (Microsoft® Corp, USA) and a running 11-breath average was obtained. The peak oxygen consumption during the exercise was recorded as the peak oxygen consumption ($\dot{V}O_{2peak}$). The variable was expressed in absolute ($L.min^{-1}$) and relative ($ml.kg^{-1}.min^{-1}$) terms, with the latter as a function of body mass. Other key respiratory variables measured were carbon dioxide production ($\dot{V}CO_2$), minute ventilation ($\dot{V}E$) and respiratory exchange ratio (RER).

3.3.2 Pilot study

A pilot study, with 12 female subjects of age 27.3 ± 9.5 yrs, weight 61.3 ± 9.7 kg, height 1.66 ± 0.08 m, Est. BF 31.3 ± 4.2 % and Est. FFM 42 ± 6.7 kg (Mean ± SD) was conducted by the author. Average speed used for the IBT was 3.1 ± 0.3 mph. Hence, similar characteristics, other than mean age was observed for the subjects in the pilot and the present study.

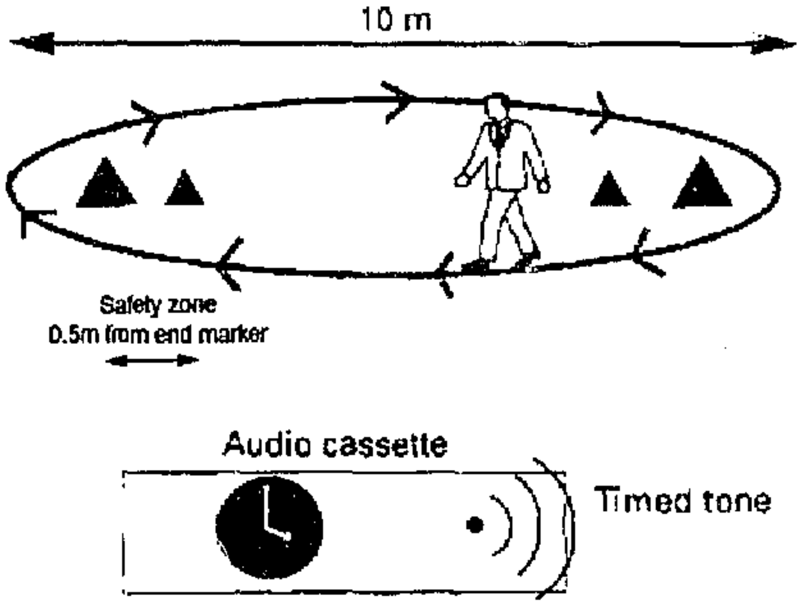
Subjects performed the exercise test twice with at least 7 days between sessions. Variables measured during the tests, including heart rate, oxygen saturation, rating of perceived exertion, $\dot{V}O_{2peak}$ and respiratory exchange ratio, were not significantly different ($p>0.05$). Relative reliability measure using correlation analysis revealed a very strong relationship between $\dot{V}O_{2peak}$ ($r= 0.91$, $p< 0.0001$), and RER ($r = 0.89$, $p= 0.0001$) obtained during both tests. Heart rate measured during the first test correlated with that measured during the second test, however, only a moderate relationship was evident ($r=0.62$, $p= 0.02$).

Relative reliability was also analysed using the Bland and Altman method (Bland & Altman, 1986). Analysis of the plots of difference between test versus the mean of differences revealed that all subjects fall within the 95% Limits of Agreement bounded by ± 1.96 SD for $\dot{V}O_{2peak}$ (+3.76 to –3.87 $ml.kg^{-1}.min^{-1}$) and respiratory exchange ratio (+0.07 to – 0.06). Although an outlier was observed in the heart rate plot, this was attributed to the large age differences with the subjects.

Overall, results from the pilot study concluded that with the significant correlation and small limits of agreement, the IBT is a reliable measure of $\dot{V}O_{2peak}$. In addition, with all the subjects meeting the 3 criterion measure of $\dot{V}O_{2max}$ ($\dot{V}O_2$ plateau, >85% age predicted HR_{peak}, Respiratory exchange ratio >1.15), the protocol has also proven its capability to stress individuals to maximal exercise intensity.

3.3.3 Shuttle walking test

The Shuttle walking test (SWT), developed by Singh et al (1992) consists of 12 levels, each lasting a minute. Following the pace indicated by the sound of single bleeps played on a pre-recorded cassette, participants walked along a 10 m course demarcated by two markers. As indicated in the operations manual, the markers were placed 0.5 meters from each end so as to avoid abrupt turnings. Another two markers were placed 0.5 meters from the end markers to identify the 'safety zone' (Figure 3).



<u>**Figure 3.**</u> **Illustration of the set up for the SWT adapted and modified from Payne & Skehan (1996)**

Similar to the IBT, the SWT is incremental in nature. Starting with a speed of 0.5m/s, the walking pace increased marginally by 0.17 m/s every minute. A detailed protocol, with the various levels and walking speed, is shown in Table 2. The increase in speed is indicated by the sound of a triple bleep. The aim for the participant is to complete each shuttle before the beep sounds.

Prior to each test session, participants were asked to perform a three-minute practice walk in order to warm-up and familiarise themselves with the task. A standard recorded instruction was played to the participants before the commencement of the test. For first minute of the test, the investigator accompanied the participants so as to help establish an appropriate pace for the walk, but from then on completed the rest of the test on their own. Participants were required to wait at the marker if they completed the particular shuttle early and to proceed only when the next beep sounded. Throughout the test, standardized instructions were provided at the end of each minute to remind

participants of the increase in speed. No encouragement was provided during the test. In accordance with guidelines from the manufacturer's manual, the tests were terminated if participants experienced any discomfort (e.g. breathlessness) and / or were unable to complete the shuttle within the specific time frame for that level (i.e. landing outside the 'safety zone' when the second beep sounded).

Table 2. **Protocol for shuttle walking test (SWT)**

10m Shuttle Walking Test – 60s increments					
			No. of shuttles		
Level	Speed ($km.hr^{-1}$)	Time/ shuttle (s)	Level	Total	Distance (m)
1	1.80	20.00	3	3	30
2	2.41	15.00	4	7	70
3	3.03	12.00	5	12	120
4	3.63	10.00	6	18	180
5	4.25	8.57	7	25	250
6	4.86	7.50	8	33	330
7	5.47	6.67	9	42	420
8	6.08	6.00	10	52	520
9	6.69	5.46	11	63	630
10	7.31	5.00	12	75	750
11	7.92	4.62	13	88	880
12	8.53	4.29	14	102	1020

Total no. of shuttles = Total no. of shuttles completed at the END of that level (e.g. 6 completed levels = 33 shuttles)

Adapted from Singh, Morgan and Hardman (n.d.)

3.3.4 Heart rate and oxygen saturation

Values for both heart rate (beats per minute or bpm) and oxygen saturation (% saturation) were monitored throughout the sessions for both exercise tests. Prior to each test, subjects were rested on a chair for approximately a minute before resting measurements of heart rate (HR_{rest}) and oxygen saturation (SpO_{2rest}) were obtained. Similar measurements were also recorded after the warmup, at the end of each minute and throughout the recovery phase for both exercise tests. Peak heart rate and oxygen saturation were expressed as HR_{peak} and SpO_{2peak} respectively. The age- predicted heart rate peak was calculated using the formula presented by Tanaka et. al (2001).

$$Age\ predicted\ HR_{peak}\ (bpm) = 208 - (0.7 * age\ (yrs)) \tag{2}$$

The percentage of age predicted HR_{peak} (% AP-HR_{peak}) was calculated using the formula shown below.

$$\%AP - HR_{peak} = \left(\frac{HR_{peak}\ (bpm)}{Age\ predicted\ HR_{peak}\ (bpm)} \right) * 100 \tag{3}$$

HR was monitored using a Polar S610 heart rate monitor interfaced with T61 chest strap (Polar Inc, Finland). Data was stored into the Heart Rate monitor's memory at 5 sec intervals and was downloaded into the Polar Precision Performance software using an infrared interface (Version 3, Polar Inc, Finland).

SpO_2 was monitored via the use of hand held Pulse Oximeter (Datex.Ohmeda TuffSat™, USA). The finger probe (Datex.Ohmeda OxyTip®+ Finger Sensor [OXY-F-UN], USA) was attached and secured to the middle finger after the site was prepared with isopropyl alcohol swabs. To prevent any motion artefact, the flexible cable was secured to the body using surgical tape.

3.3.5 Differentiated rating of perceived exertion

Rating of perceived exertion (RPE), an indicator of increase in sensory perceptions during exercise, was measured using a Borg Category Ratio (CR10) scale (Appendix D). Even though initially designed to measure pain levels, it also provides a direct, valid and reliable estimate of perceived exertion (Borg, 1998, pp.49-52). As shown by Pandolf (1982) and Robertson, Gillespie, McCarthy, and Rose (1979), differentiated RPE provides a clearer picture of the exertion level during exercise. Hence, two measurements of RPE will be taken during the exercise test. Participants were required to indicate perceived effort of the chest (RPE-C) and legs (RPE-P) at the end of each minute of the test. General instructions on the use of the Borg scale were provided before the participant performed the warm-up for each exercise test and were as follows:

> This is a scale (from 0 to 10) that you will use to indicate your effort during the exercise test. During each minute of the test, I will be asking you to identify an appropriate level of effort (ie. light, moderate etc) and indicate a number corresponding to that. I will be asking for your perceived effort on two locations. The first is the chest or what we term as Central RPE. This indicates your perceived exertion on your chest (ie. how hard you are exerting at your chest and this could relate to either breathlessness or pain in the chest). The second location is the leg or what we term Peripheral RPE. This indicates how hard you are exerting at the level of your legs and could relate to fatigue, tiredness and/ or pain.
>
> For this purpose, 'very weak' (ie. 0.5 on the numerical scale, is a perception that corresponds to a 'light casual walk in the park'. 'Moderate' or 3 on the numerical scale, is a perception that indicates that the effort sense has increased but you are confident of maintaining the pace for some time. 'Extremely strong' or 10 on the numerical scale, indicate that the intensity is maximal and you need to stop the test at very short notice. It is very important that you provide the most accurate reflection of your effort during each stage of the test. During the warm-up, I will strongly encourage you to familiarise yourself with the RPE scale (ie. understanding the varying effort perception).

3.3.6 Seven day recall

The Seven Day Recall (7DR), developed by Sallis, Haskell, Wood, Fortmann, Rogers, Blair and Paffenbarger (1985) is an interviewer- administered questionnaire (Appendix E) that takes approximately 20 minutes to complete. Studies by Jacobs, Ainsworth, Hartman and Leon (1993) and Richardson, Ainsworth, Jacobs and Leon (2001) have validated the 7DR for heavy and total and very hard activities and has found these activity levels to be associated with $\dot{V}O_{2peak}$ in both men and women. To establish reliability, baseline measurements were conducted over two weeks prior to the final recall. Twenty-six participants completed both measurements. One way- ANOVA with repeated measures did not reveal any significant difference between Recall 1, 2 and 3, thus suggesting the 7DR-Total to be a reliable measure of habitual physical activity during any single week (Appendix F).

During each interview session, participants were required to recall the amount of time spent in leisure/ occupational activities of varying intensities over the past seven days. The intensities consisted of the following: sleeping, moderate (4 METs), hard (6 METs), very hard (10 METs) and flexibility/ strength exercises (Seven-day physical activity recall, 1997). The amount of time spent in the Light (1.5 METs) intensity was calculated by subtracting the total time spent in the aforementioned activities from 24 hrs in a day. 1 MET was defined as 1 $kcal.kg^{-1}.min^{-1}$. To account for inter individual variation in resting energy expenditure, the amount of time spent in each activity intensity was calculated and expressed as $MET.min.d^{-1}$.

3.3.7 Activity monitor and diary record

An objective and direct method of assessing physical activity is by the use of activity monitors. A Manufacturing Technology Inc. (MTI) activity monitor (model 7164, USA) was provided for participants during their second visit to the laboratory. The MTI activity monitor is a uniaxial accelerometer that measures movement in the vertical direction. With its magnitude and frequency range of 0.05 – 2.0 G and 0.25 – 2.5 Hz respectively, it allows accurate measurement of daily physical activities based on the activity counts per day. When validated with indirect criterion measures such as $\dot{V}O_{2peak}$, the MTI activity monitor has shown a significant relationship (Melanson & Freedson, 1995; Trost et al., 1998). These authors also suggested that the MTI is a valid and reliable instrument to measure total and patterns of physical activities.

To ensure consistency of results, all the activity monitors were calibrated using a tilt machine. With the aid of an internal real time clock and manufacturer supplied software, the activity monitor was initialised to start at 12 am on the day after collection. The epoch (sampling interval) was set at 1 min.

Participants were instructed on placement of the activity monitor on the right hand side of the hip and were required to put the activity monitor on at all times during the week (except when they were sleeping, showering and/ or involved in any water-related activities). During the same period, participants were also required to complete a simple activity diary. This was to identify and verify any discrepancies resulting from the MTI activity monitor data.

On return of the activity monitor, data was downloaded into a personal computer using the Reader Interface Unit. A macro was developed to extract the data onto an Excel spreadsheet (Microsoft® Corp, USA). Activity counts per minute ($counts.min^{-1}$), as recorded by the MTI activity monitor, was classified into the different activity intensity using the cut-offs recommended by Freedson, Melanson, & Sirard (1998). They were Light (< 1952), Moderate (1952-5724), Hard (5725-9498) and Very hard (> 9498). Similar to the 7DR, the amount of time spent in each category was calculated and expressed as $MET.min.d^{-1}$.

3.4 Data analysis

Data are presented as Mean ± SEM unless otherwise indicated. A Pearson product- moment correlation (r) was conducted to determine the relationship between the following variables: -

- performance on IBT ($\dot{V}O_{2peak}$) vs. performance on SWT (Distance ambulated)
- individual characteristics, such as age (yrs), body mass (kg), Est. BF (%), Est. FFM (kg) and time spent in habitual physical activity ($MET.min.d^{-1}$) vs. $\dot{V}O_{2peak}$
- individual characteristics described above vs. SWT distance ambulated

Paired sample (Dependent group) Student's t- tests were conducted to identify significant differences between the following variables: -

- HR (bpm), SpO_2 (%), RPE-C and RPE-P, under the two exercise conditions
- time spent in physical activity ($MET.min.d^{-1}$), as measured by 7DR and MTI activity monitor

Individual subject's data at peak intensity of IBT and SWT is shown in Appendix G. Student's t-test values, with associated p values are shown in Appendix H.

Statistical analysis was performed using GraphPad Prism version 3.00 for Windows (GraphPad Software, California USA) and SPSS Version 10 for Windows (SPSS Inc, Illinios USA). Statistical significance was set at $p < 0.05$.

CHAPTER 4

RESULTS

4.1 Pre- exercise measurements

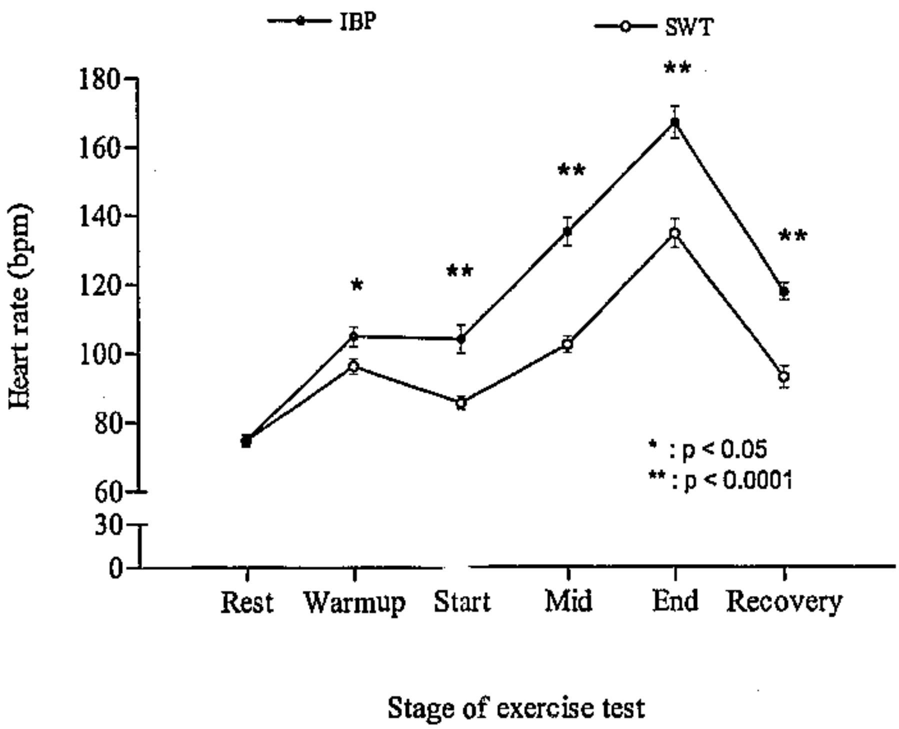
Prior to the beginning of each exercise test, resting measurements for HR_{rest} and SpO_{2rest} were obtained. There were no significant differences in HR_{rest} between IBT and SWT test (Figure 4). Although SpO_{2rest} for IBT (97.8 ± 0.2 %) and SWT (97.1 ± 0.3 %) showed only a 0.7% difference, this was found to be significant ($p = 0.0255$). Inspection of individual values revealed a difference in the range of SpO_{2rest} (%) for SWT (Range: 91 – 100%) and IBT (Range: 95 – 100%), with the small number of subjects with lower SpO_{2rest} in the SWT accounting for the significant finding.

4.2 Physiological responses during exercise

All participants performed both the SWT and IBT, resulting in similar, linear increases in heart rate over the course of exercise (Figure 4). Paired sample t-test showed that HR was significantly higher after warmup ($p < 0.05$) and during all stages of the exercise ($p < 0.0001$). For the IBT, this was more pronounced at the end of the test, with the IBT eliciting an average HR_{peak} of 31 bpm higher than that in the same subjects who performed the SWT. When expressed in terms of % A-P HR_{peak}, IBT

produced ~ 20% higher % A-P HR_{peak} (97.1 ± 2.3 % vs. 78.4 ± 2.3 %, $p < 0.0001$). SpO_2 decreased during both SWT and IBT but was not significantly different.

Visual inspection of gas exchange analysis results obtained from the IBT showed that 30 subjects achieved a plateau in oxygen consumption during the final minute of exercise (Appendix I). Mean $\dot{V}O_{2peak}$, $\dot{V}E$ and RER values for all subjects were 29.4 ± 1.3 $ml.kg^{-1}.min^{-1}$, 1.8 ± 0.1 $L.min^{-1}$ and 1.25 ± 0.02 respectively. These results (plateau in $\dot{V}O_2$ and RER > 1.15), together with the attainment of > 85% % A-P HR_{peak} described in the previous section, verified that the test produced maximal oxygen consumption from the subjects.



<u>Figure 4.</u> **Heart rate response during both exercise tests**

4.3 Perceived exertion during exercise test

In parallel with the heart rate response described earlier, an increase in the rating of perceived exertion was observed throughout both IBT and SWT (Figure 5). The test commenced relatively easy for both the IBT and SWT, with an RPE-C and RPE-P of 0.1 and 0.4 respectively. Even so, IBT was perceived to be significantly harder at the start. By mid stage, a more significant difference can be observed during tests. Both RPE-C and RPE-P during SWT were not really different between the start and the midpoint of the test.

At peak intensity, RPE-C_{peak} and RPE-P_{peak} were two times greater during IBT and was shown to be highly significant ($p < 0.0001$). Overall, the IBT was perceived to be a much harder test than the SWT.

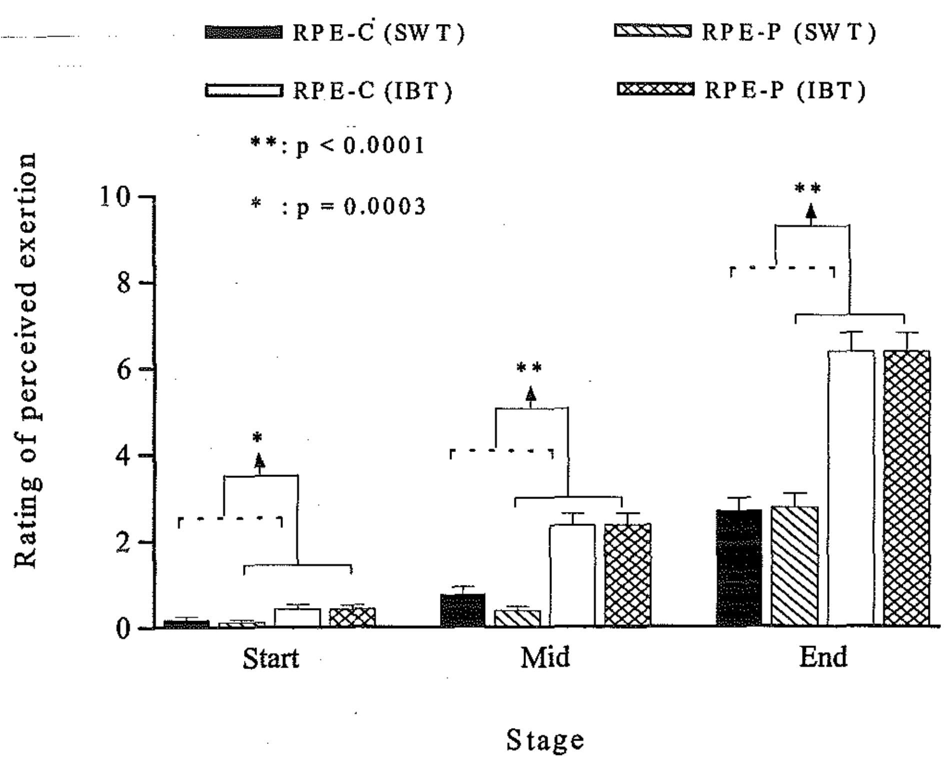


Figure 5. **Differentiated Rating of perceived exertion at peak intensity**

Between the differentiated perceived exertion (RPE-C and RPE-P), there were no significant differences. RPE-C and RPE-P were similar at all stages and followed the same increment pattern over the time course of both tests.

4.4 Relationship between peak oxygen consumption ($\dot{V}O_{2peak}$) and distance ambulated on SWT

Figure 6 below shows the scatter plot of the relationship between $\dot{V}O_{2peak}$ (IBT) and distance ambulated (SWT). Pearson product moment correlation analysis between the two variables provided a moderate and yet significant relationship (r= 0.58, p= 0.0005). A square of the 'r' value revealed that only 33% variance in SWT distance could be explained by variance in $\dot{V}O_{2peak}$ during IBT.

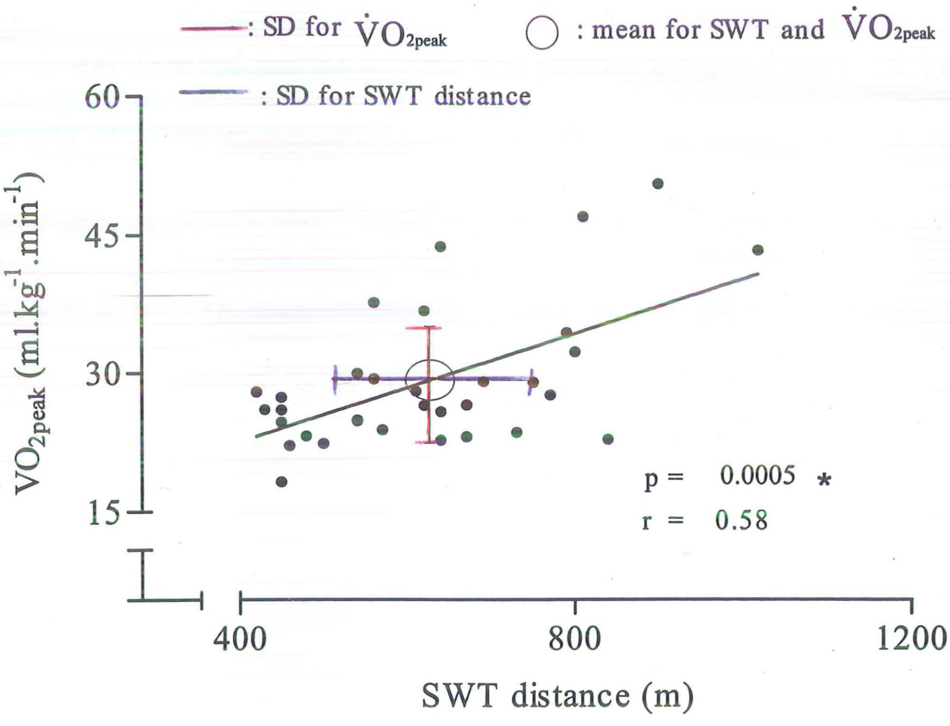


Figure 6. **Scatter plot showing relationship between peak oxygen consumption ($\dot{V}O_{2peak}$) and SWT ambulated distance.**

It should be noted that even though a relationship existed between $\dot{V}O_{2peak}$ and SWT distance, a disperse in individual results was observed. Group mean results with SD for both $\dot{V}O_{2peak}$ and SWT distance were plotted using a simple circle and whisker plot (Figure 6). Analysis of the plot and individual subject results revealed a wide range for both $\dot{V}O_{2peak}$ (Mean 29.4 ± 7.8 ml.kg^{-1}.min^{-1}; Range: 18.2 to 50.5 ml.kg^{-1}.min^{-1}) and SWT distance ambulated (Mean 624.5 ± 148.9 m; Range: 420 to 1020 m). The standard deviation for the SWT was greater than that for the IBT- thus suggesting a wider spread of results for the SWT.

It was observed that the subjects who attained a $\dot{V}O_{2peak}$ above the group mean (> 29 ml.kg^{-1}.min^{-1}) displayed a larger range $\dot{V}O_{2peak}$ as compared to the rest of the subjects who achieved a $\dot{V}O_{2peak}$ less than the group mean (29.4 to 50.5 ml.kg^{-1}.min^{-1} and 18.2 to 29.4 ml.kg^{-1}.min^{-1} respectively). However, for the SWT distance, the spread was similar for both of the groups. (Range: 560 to 1020 m and 420 to 840 m)

4.5 Variables influencing performance on SWT and IBT

Univariate correlation analysis (two-tailed) was conducted on selected variables identified in the second research question, including: age (yrs), b. wt. (kg), est. BF (%), Est. FFM (kg), MTI- Total ($MET.min.d^{-1}$), 7DR- Total ($MET.min.d^{-1}$). Other physiological measurements obtained during SWT, including HR_{peak}, % A-P HR_{peak}, RPE-C, RPE-P and distance were also analysed. $\dot{V}O_{2peak}$ was the only variable measured during IBT that was included. The correlation matrix is shown in Table 3.

4.5.1 Effect of age

Age was negatively correlated with both $\dot{V}O_{2peak}$ and SWT distance (Table 3), with a stronger relationship for the $\dot{V}O_{2peak}$ ($r= 0.61$, $p \leq 0.0001$). 37 % of the variance in $\dot{V}O_{2peak}$ is associated with age as compared to only 23 % in the SWT. Est. BF was the only other variable that was highly correlated with age. A moderate relationship with age was also observed for Est. FFM, 7DR-Total and MTI-Total ($p < 0.05$).

The significant influence of age on the aforementioned variables prompted further analyses. The entire group was ranked according to age and an equal number from either end of the age ranking were chosen and stratified for further analysis. The two age distinguished groups (n = 10) were: 31- 40 yrs [Age: 36.2 ± 2.3 yrs (Mean ± SD), Range: 32 – 40yrs] and ≥61 yrs [Age: 62.5 ± 1.3 yrs, Range: 61-65 yrs]. Both 31-40 yrs and ≥ 61 yrs group presented with similar individual characteristics for weight and height. Estimated body fat and fat free mass were significantly higher: 40.6 ± 2.8 % vs. 28.4 ± 2.3 % and lower 37.8 ± 1.8 kg vs. 44.2 ± 1.9 kg ($p < 0.05$) respectively, for the ≥ 61 yrs group.

Table 3. Univariate correlation matrix for selected variables

Variables	Age	B. wt.	Est. BF	Est. FFM	HR_{peak}	% A-P HR_{peak}	RPE-C	RPE-P	Distance	$\dot{V}O_{2peak}$	7DR-Total	MTI-Total
Age (yrs)		0.13	**0.67 ****	**-0.40**	0.19	-0.19	-0.17	-0.21	**-0.48**	**-0.61 ****	**0.45**	**0.49**
B. wt. (kg)			**0.47**	**0.67 ****	0.20	0.13	-0.29	-0.08	-0.18	0.26	0.00	-0.34
Est. BF (%)				**-0.33**	0.12	-0.15	-0.30	-0.25	**-0.50**	**-0.40**	**0.45**	0.14
Est. FFM (kg)					0.11	0.27	-0.05	0.13	0.20	**0.56**	-0.38	**-0.43**
HR_{peak} (bpm)						0.09	-0.05	0.18	[illegible]	0.09	0.24	-0.03
% A-P HR_{peak}							**0.42**	**0.52**	**0.62 ****	0.02	-0.26	-0.20
RPE-C								**0.92 ****	**0.41**	-0.13	-0.20	0.07
RPE-P									**0.47**	-0.01	-0.22	-0.07
SWT Distance (m)										**0.44**	-0.35	-0.19
$\dot{V}O_{2peak}$ ($L.min^{-1}$)											-0.32	-0.32
7DR- Total ($MET.min.d^{-1}$)												0.14
MTI- Total ($MET.min.d^{-1}$)												

Note. Values in bold represents variables that are significantly correlated ($p < 0.05$). ** represents highly significant $p \leq 0.0001$

Figure 7 shows that the 31 – 40 yrs group achieved a significantly higher absolute $\dot{V}O_{2peak}$ (2.1 ± 0.1 $L.min^{-1}$ vs. 1.6 ± 0.1 $L.min^{-1}$, $p < 0.05$). In fact, the mean absolute $\dot{V}O_{2peak}$ for the 31 – 40 yrs group was 25 % higher than that achieved by all the subjects from the ≥ 61 yrs group. There was a wide range in absolute $\dot{V}O_{2peak}$ values between the two groups.

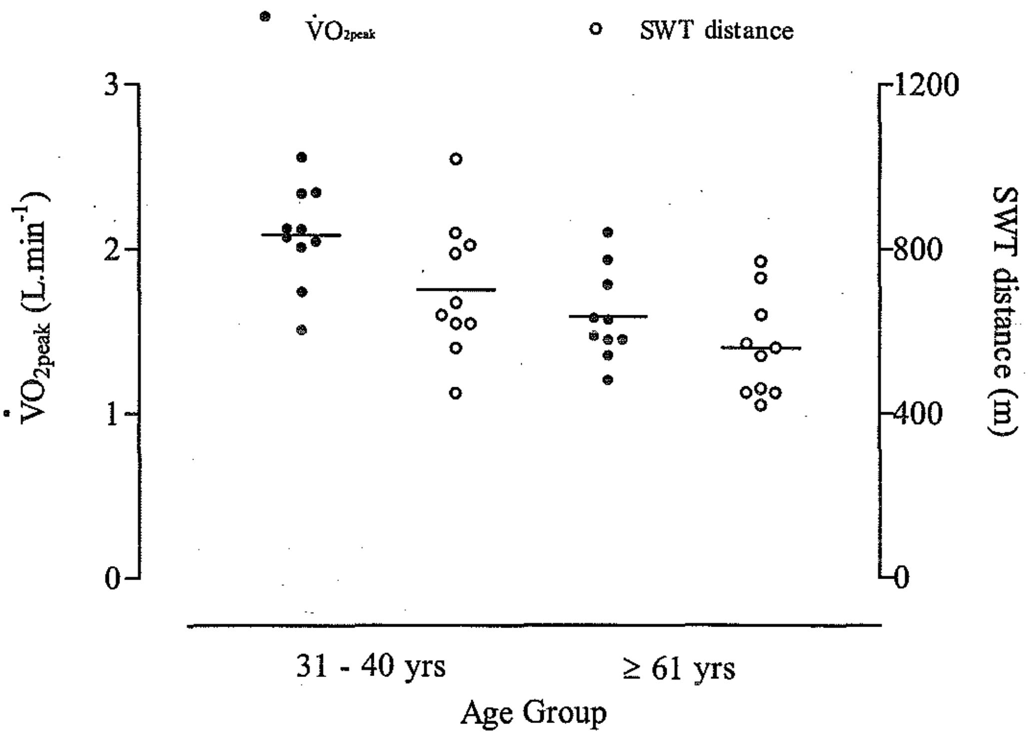


Figure 7. **Scattergram illustrating the range of absolute $\dot{V}O_{2peak}$ (•) and SWT distance (◦)**

Similar results were also observed for the SWT distance (Figure 7). Mean distance ambulated was 21 % higher in the 31 – 40 yrs group (702.0 ± 51.8 vs. 559.0 ± 38.5, $p < 0.05$). A spread was also observed with the SWT distance but it was smaller than observed earlier in the $\dot{V}O_{2peak}$ (420 to 770m vs. 450 to 1020 m).

4.5.2 Effect of body composition

From Table 3 above, B. Wt. demonstrated a highly significant relationship with Est. FFM ($p \leq 0.0001$). Conversely, a significant relationship was observed between Est. BF and B. Wt. ($r = 0.47$) and only a moderate relationship was observed between Est. BF and Est. FFM ($r = -0.33$, $p < 0.05$)

Results also showed that Est. BF was the only variable that was significantly correlated with both SWT and IBT, with a weaker relationship for the latter test. Est. BF can explain 16 % of the variance in IBT and 25% of the variance in SWT. It should be noted that the relationship for Est. BF with the two tests was negative. Therefore, an increase in Est. BF would result in lower $\dot{V}O_{2peak}$ and SWT distance. Est. FFM was positively correlated with $\dot{V}O_{2peak}$ ($p < 0.05$) but not with SWT distance. The strongest coefficient of determination (31 %) was observed for this variable.

In terms of habitual physical activity, a positive relationship was observed for Est. BF with 7DR-Total and a negative relationship for Est. FFM with MTI-Total. Both correlations were moderate ($p < 0.05$).

4.5.3 Physical activity level

The measurements of habitual physical activity between 7DR-Total and MTI-Total did not relate to each other. In addition, both 7DR-Total and MTI-Total showed very weak relation with performance on the SWT (distance) and IBT ($\dot{V}O_{2peak}$). Coefficient of determination for MTI-Total was only 3 and 10 % for SWT and IBT

respectively. With the 7DR-Total, habitual physical activity could only account for 10 % variance in $\dot{V}O_{2peak}$ and SWT distance.

4.5.4 Psychometric and physiological variables

The very strong relationship observed between RPE-C and RPE-P ($r = 0.92$, $p < 0.0001$) reinforced the previous results that showed that both central and peripheral perception of effort were not significantly different during SWT. This supported the earlier finding that both differentiated scales were not different during SWT (Figure 5). Both RPE-C and RPE-P showed only a moderate relationship ($p < 0.05$) with distance ambulated during SWT and % A-P HR_{peak}. In addition, % A-P HR_{peak} was correlated significantly with SWT distance ($p < 0.0001$). No relationship was observed for HR_{peak} with other variables.

CHAPTER 5

DISCUSSION

The primary purpose of this study was to determine the validity of the SWT as a field measure of cardiorespiratory fitness in healthy adult women. A secondary purpose was to identify how individual characteristics such as age, body composition and levels of habitual physical activity influence performance on the SWT. The major finding was the discovery of a moderate relationship between performance on SWT (distance ambulated) and IBT ($\dot{V}O_{2peak}$). In addition, this study has identified age and body composition, specifically Est. BF, as variables that could influence the distance ambulated on the SWT.

5.1 SWT as a valid field measure of cardiorespiratory fitness

This is the first ever study that has evaluated the SWT with cardiorespiratory fitness in healthy adult women. The observed moderate correlation between SWT distance and $\dot{V}O_{2peak}$ ($r = 0.58$) is lower than that shown in previous studies in patients with chronic heart failure ($r = 0.83$) (D. J. Green et al., 2001; Morales et al., 1999) and chronic airway limitation ($r = 0.88$) (Singh et al., 1994). Even though Lewis et al (2001), in their work with patients awaiting cardiac transplantation showed a correlation of 0.73, it was highly significant ($p = 0.0001$) with all subjects attaining values within the 95% confidence interval. The apparent discrepancy between the findings of this study and those above are unlikely related to methodological differences, since the

experimental techniques and protocols were very similar. More probably, the subject characteristics (i.e. patient vs. healthy populations) are the key factors explaining the difference in findings; specifically the impaired physiological and psychometric responses of the patient groups.

Comparison of the $\dot{V}O_{2peak}$ values (Mean 29.4 ± 7.8 $ml.kg^{-1}.min^{-1}$) obtained in this study with those reported previously in similar populations using similar testing was made. Jackson et al. (1996) reported the aerobic power of women aged 39.4 ± 9.6 yrs to be 31.6 ± 8.3 $ml.kg^{-1}.min^{-1}$. Similar values of $\dot{V}O_{2peak}$ for sedentary women were also observed by Tanaka et al. (1997) and Stevenson, Davy and Seals (1994) respectively. The marked similarity suggests that the sample used in this study is representative of the adult women population as a whole and was not biased in terms of their level of cardiorespiratory fitness. Hence, it strengthens the interpretations on the results for validity and usefulness of the SWT.

With patient populations, typical $\dot{V}O_{2peak}$ values achieved were shown to be 18.3 ± 2.0 $ml.kg^{-1}.min^{-1}$ (D. J. Green et al., 2001), 15.2 ± 4.4 $ml.kg^{-1}.min^{-1}$ (Lewis et al., 2001) and 14.2 ± 4.1 $ml.kg^{-1}.min^{-1}$ (Singh et al., 1994). These were approximately half of that reported with the healthy adult women in the present study and evidently show the loss in functional capacity associated with their pathology. However, the issue of mixed genders used in these studies need to be considered when comparing the data. The wide spread of $\dot{V}O_{2peak}$ values measured in this study compared to those involving patient populations may be related to the large age range used (32 to 65 yrs). Even though similar age ranges were used in studies involving patient populations, the $\dot{V}O_{2peak}$ variance was not as wide (Lewis et al., 2001; Morales et al., 1999; Singh et al.,

1994). The factors above suggest that these patient populations were functionally limited due to their conditions per se and the associated limitations obscured the effect of age to physical function (Huang et al., 1998).

Previous studies have demonstrated varying distances ambulated on the SWT across different patient groups. Chronic heart failure patients (NYHA class II and III) were shown to complete an average of 401 to 503 m on the SWT (D. J. Green et al., 2001; Lewis et al., 2001; Morales et al., 1999). In patients with chronic airway limitation (fro whom the SWT was initially designed), the mean SWT ambulated distance was lower, ranging from 177 to 375 m (Dyer et al., 2002; Singh et al., 1994; Singh et al., 1992). Notably, breathlessness was found to be the key factor in determining the limitation of subjects' walking speed. Between healthy individuals, the mean SWT distance of 624.5 ± 148.9 m in this present study was more than two times that achieved by healthy subjects (≥ 70 yrs) in the study by Dyer et al. (2002). However, the current SWT distance is lower than that achieved by healthy adult males (726.7 ± 161.2 m) (Webb et al., 2002). Age and gender differences respectively, are likely reasons for these disparities.

Evaluation of the cardiovascular responses indicates that the HR_{peak} attained during the SWT was significantly lower than that on the IBT. To the author's knowledge, this is the first study to compare HR responses between the two tests in healthy individuals. Previous work with clinical populations revealed inconsistent findings. Morales et al. (1999) and Singh et al. (1994) found that HR_{peak} was lower during the SWT. Contrary to this, D.J. Green et al. (2001) showed that HR_{peak} during SWT and IBT were not significantly different. The smaller sample size and patient

characteristics (cardiac patients with clinically stable conditions) used for the latter study as acknowledged by the authors may limit interpretations of their data. In any case, the difference between the HR_{peak} during SWT and IBT for the clinical population (~ 18 bpm) was smaller than that of the healthy adult women (~ 31 bpm) in the current study. Analysis of % A-P HR_{peak} will help investigators understand the level of cardiovascular work achieved in both SWT and IBT. Findings of this variable (% A-P HR_{peak}) revealed that the SWT did not have as much potential as a conventional treadmill test to push subjects to perform to a higher level of their A-P HR_{peak}.

The low perceived exertion scores attained during the SWT support the findings in relation to HR. In addition, the moderate correlation between the low % A-P HR_{peak} with low RPE-P and RPE-C scores also reveal the limitations to performance of the SWT in the present population did not relate to their maximal or near maximal effort for the cardiorespiratory system. The low RPE-C and RPE-P suggests that at peak intensity of the SWT, the subjects were not limited in performance due to perceived breathlessness and leg fatigue respectively. Comparisons of such rating of perceived exertion with previous studies has to be performed with caution due to the large interindividual differences in exercise tolerance during a particular test. Also, the different scale used (eg. rating of dyspnea) and instructions given may hinder cross study data interpretation.

Nevertheless, previous clinical studies have shown similarity with the maximum rating of perceived exertion (dyspnea) between SWT and conventional treadmill exercise tests (D. J. Green et al., 2001; Morales et al., 1999); which was not demonstrated in this study. As previously mentioned, patient populations commonly were unable to continue the test due to breathlessness. Feedback obtained from the

healthy subjects in this study revealed that subjects stopped the test because of their inability to maintain the required walking pace with none reporting that exhaustion and/ or perceived breathlessness/ discomfort was a limiting factor. This was similar to that shown in the study by Dyer et al. (2002). Comparison of the walking speed attained by subjects in this study (1.79 ± 0.2 m) with maximum age- matched walking speeds reported previously revealed that subjects, at the peak level of the SWT, were walking higher than their predicted fastest gait speed (Oberg, Karsznia, & Oberg, 1993). With maximum walking speed shown to correlate with lower extremity muscle strength (Bohannon, 1997), it seems logical to deduce that the performance on the SWT in healthy adult women is limited by their lower extremity musculoskeletal and/ or locomotor ability. Whilst impairment in muscle function, associated with muscular fatigue, is commonly associated with progressive exercise tests (Green & Patla, 1992), the similarity between RPE-C and RPE-P, which differentiates between chest and leg muscular fatigue (Pandolf, 1982), suggests that it was not the case for the present study. The much higher functional capacity in healthy subjects make it more likely that locomotor limitation precede the cardiorespiratory factors (ie. exhaustion or breathlessness) in determining SWT ability.

Although not previously demonstrated with healthy individuals, the present findings support the statement by Steel (1996) that the SWT is inherently submaximal in nature. Therefore, it could not determine the maximal stress potential of the cardiorespiratory system in healthy adult women, but instead, as suggested by Macsween et al. (2001) " is a direct measure of locomotive ability, with only a potential for inferring aerobic power from the result" (p.809).

5.2 Influence of age, body composition and habitual physical activity on SWT performance

To further elucidate the factors limiting SWT in the present study, the relationship with selected variables was determined. The findings were that SWT performance is related to subjects' age and quantity of body fat. Interestingly, participating with higher levels of habitual physical activity did not improve performance on the SWT.

5.3.1 Influence of age on SWT performance

The widely reported age- related decline in $\dot{V}O_{2peak}$ (Fitzgerald et al., 1997; Jackson et al., 1996) likely explains the findings obtained. It has been well documented that the reduction in a combination of central circulatory function, such as maximal heart rate, maximal stroke volume, maximal arteriovenous O_2 difference, respiratory muscle reserve function etc., contribute to the associated age- related decline in aerobic capacity (Cunningham, Paterson, Koval, & St Croix, 1997; Lakatta, 1993). Although the relationship for age and SWT distance ($r = -0.48$) was not as strong as that observed with $\dot{V}O_{2peak}$ ($r = -0.61$), both were significant. Webb et al. (2002) evaluated the age-related standards for performance of the SWT in healthy adult men and found similar decrements in SWT distance with age. As previously discussed, the lower SWT distance achieved in patient populations is due in large part to their functional capacity per se, which obscures such age differences. As the SWT is shown to lack the ability to discriminate functional capacity with healthy adult women, it is logical that the age-associated decline in SWT distance could be due to the age related changes in lower

extremity muscle mass (Fleg & Lakatta, 1988), which consequently influenced an individual's maximal walking ability (Bohannon, 1997; Oberg et al., 1993).

5.3.2 Influence of body composition on SWT performance

The age- associated decline was also demonstrated with Est. FFM, but not Est. BF. Est. BF and Est. FFM in this study were found to be higher than that shown in Kriketos, Sharp, Seagle, Peters and Hill (2000). They also found a relationship for the Est. BF and Est. FFM with $\dot{V}O_{2peak}$ which was stronger than that shown in this study (Table 4). On the contrary, Est. BF and Est. FFM, together with its associated correlation with $\dot{V}O_{2peak}$, were consistent with that shown with a study by Toth et al. (1994). The dissimilarity in relationship with cardiorespiratory fitness, shown with the study by Kriketos et al. (2000), could be due to the mathematical expression of $\dot{V}O_{2peak}$. They used $\dot{V}O_{2peak}$ ($L.min^{-1}$) expressed in terms of fat free mass ($ml.kg^{-1}FFM.min^{-1}$) instead of absolute $\dot{V}O_{2peak}$ ($L.min^{-1}$), as used in this study.

The association of the Est. BF with age, accompanied by its relation with SWT distance and $\dot{V}O_{2peak}$, suggests that as an individual's performance on either test is partly influenced by the age related increase in Est. BF. The significant contribution of Est. BF on SWT performance suggests that the amount of 'non- muscular' weight carried by the women exerts a larger impact on their ability to walk further (or faster) on the SWT. To provide a more detailed picture of the influence of body composition, Est. FFM was also analysed. This variable was described earlier as a potential factor influencing the maximum walking speed. Findings from the current study showed conflicting relationships with $\dot{V}O_{2peak}$. However, the influence of age on Est. FFM is

consistent with that shown by Fleg & Lakatta (1988). Similar to the study by Toth et al (1994), $\dot{V}O_{2peak}$ is the only significant independent correlate with Est. FFM. Goran, Fields, Hunter, Herd and Weinsier (2000) in their examination of the effect of body fat and fat free mass on aerobic fitness in adult women also found significant correlation between Est. FFM and $\dot{V}O_{2peak}$. As the protocol of the IBT requires subjects to progress up an incline, it seems logical that subjects with higher muscle mass are able to cope with the muscular demands of the test better and subsequently able to push themselves to a higher cardiopulmonary limits. Furthermore, as muscle mass is more metabolically active than fat mass (Goran et al., 2000), a higher proportion of Est. FFM will imply a higher oxygen utilisation ability in the system. Conversely, Hunter, Weinsier, McCarthy, Enette Larson-Meyer and Newcomer (2001) suggested that the difference in $\dot{V}O_{2peak}$ between African- Americans and Caucasian- Americans may not be influenced by Est. FFM alone. Haemoglobin (Hb) concentration, muscle aerobic capacity and leg lean tissue mass may also contribute to the associated difference. Such detailed analysis is beyond the scope and time constraints of the present study. Nonetheless, the issue of measuring lower limb fat free mass may have implications on the interpretations of SWT performance data in future studies and warrants further investigation.

The present findings suggests that the performance on the SWT is not influenced by the muscle mass per se but rather by the amount of body fat that is not contributing to the work being performed. It is acknowledged that the Est. FFM was calculated using Est. BF as determined by skinfold measurements. This merely provides an estimate of the body fat around the body. Specifically, lean leg muscle mass as suggested by Hunter et al. (2001), should have been evaluated. Given that the task of walking is driven by the lower extremity, measurement of fat free mass on the limbs will provide a more accurate indication of the amount of muscle available in the exercising limb. In

addition, measures of peripheral muscle strength used in the study by Troosters, Gosselink, and Decramer (1999), could provide clearer determinants for walking speed or performance during SWT.

5.3.3 Influence of habitual physical activity on SWT performance

The single published study evaluating the use of SWT on healthy adult men by Webb et al. (2002) compared the levels of self-reported physical activity with performance on SWT. Their findings were congruent with those of the present investigation in that engaging in high levels of physical activity does not predict better performance on the SWT. These results contradict those that have related physical activity with $\dot{V}O_{2peak}$ (Berthouze et al., 1995; Stofan, DiPietro, Davis, Kohl, & Blair, 1998).

Previous studies have also demonstrated a lower level of physical activity with older subjects (Berthouze et al., 1995; Huang et al., 1998; McMurray et al., 1998; Talbot et al., 2000). On the contrary, both measures of habitual physical activity used in the current study (MTI-Total and 7DR-Total) showed a significant positive relationship with age and demonstrated that the older subjects were more active than their younger counterparts. One reason may be due to the sampling of the subjects, which could have lead to some form of inclusion bias. The older subjects who volunteered for this study were mainly retirees who may have additional time to participate in habitual physical activities more regularly whereas most of the younger participants are either working individuals or full- time mums with young families. Therefore, the time demands of individuals may vary across the age spectrum. The cross-sectional design of the present investigation means that conclusions about such matters cannot be made. A broader,

longitudinal study of time demands, physical activity levels and activity choices would be required.

Findings from the activity monitoring also showed that both instruments were not in agreement in terms of the total physical activity participated. The poor correlations obtained between 7DR and MTI activity monitor demonstrates the limitations of activity monitoring such as recall bias and intrinsic ability of instruments to accurately monitor physical activity (Ainsworth, 2000; Coughlin, 1990). The methods and accuracy involved in monitoring levels of physical activity especially in adult women are variable and raises much debate (Booth, 2000; Cauley, LaPorte, Sandler, Schramm, & Kriska, 1987; Lamonte & Ainsworth, 2001). Moreover, the value of subjective versus objective assessment is still unclear (Ainsworth, 2000; Freedson & Miller, 2000). While intriguing and important, the evaluation of physical activity monitoring tools extends beyond the scope of the present study. Developments in the research on activity monitoring should be directed towards distinguishing what each measurement represents and how they relate to physiological stress during daily activities.

The spread of $\dot{V}O_{2peak}$ values within the 31-40 yrs group also suggest a wide variability in functional capacity. However, it is highlighted that although the younger subjects participated in lower levels of physical activities, they had a much higher functional capacity than their older counterparts. Berthouze et al. (1995) suggested that "mean habitual energy expenditure, an indicator of physical activity levels, is the most important factor of $\dot{V}O_{2peak}$ variation" (p.1175). Conversely, a more recent study by Talbot et al. (2000) showed that high-intensity leisure time physical activity accounted

for an increased variance in the $\dot{V}O_{2peak}$ achieved. Although measurements were made for time participated in different activity categories, the primary purpose and design of the current study limits statistical power to propose any meaningful conclusions in this regard.

5.3 Conclusion and recommendations

This study is the first to evaluate the validity of the SWT in healthy adult women. The hypothesised correlation between performance on SWT and IBT, whilst significant, was only moderate and was shown to be lower than that observed in previous studies with clinical populations. In addition, findings from this study suggest that the performance of the SWT in healthy adult women is questionable and warrants further investigation.

The findings from the present study have contributed significantly to the field of exercise science by firstly providing data on SWT performance in healthy adult women. Secondly, they provide directions for further research into the use of the SWT in healthy populations. Several recommendations are made to improve future investigations.

1. To improve statistical power with correlational studies and allow for multivariate comparison (regression), it is recommended that a larger sample size be recruited.

2. To understand the actual aerobic/ anaerobic response during SWT, assessment of $\dot{V}O_{2peak}$ using a portable gas analyser is recommended. This analysis will also provide a direct comparison of the cardiorespiratory fitness, instead of inferring from the distance ambulated.

3. To provide more accurate body composition analysis, fat free mass on the lower limb should be specifically measured. Additional measurements for lower limb muscular strength may aid in the discrimination of walking ability and subsequently SWT performance between individuals.

4. As walking speed was shown to be the key limitation to performance on the SWT, future studies may look into isolating this variable. Age and Est. BF matched individuals could be divided into different categories based on maximal walking speed. This may allow the true effect of walking speed on the SWT performance to be illustrated.

REFERENCES

Ainsworth, B. E. (2000). Issues in the assessment of physical activity in women. Research Quarterly for Exercise & Sport, 71(2 Suppl), S37-42.

Ambrosino, N. (1999). Field tests in pulmonary disease. Thorax, 54(3), 191-193.

Baarends, E. M., Schols, A. M., Mostert, R., Janssen, P. P., & Wouters, E. F. (1998). Analysis of the metabolic and ventilatory response to self-paced 12-minute treadmill walking in patients with severe chronic obstructive pulmonary disease. Journal of Cardiopulmonary Rehabilitation, 18(1), 23-31.

Bader, D. S., Maguire, T. E., & Balady, G. J. (1999). Comparison of ramp versus step protocols for exercise testing in patients > or = 60 years of age. American Journal of Cardiology, 83(1), 11-14.

Balady, G. J., Berra, K. A., Golding, L. A., Gordon, N. F., Mahler, D. A., Myers, J. N., & Sheldahl, L. M. (2000). ACSM's guidelines for exercise testing and prescription (6th ed.). Baltimore, Md.: Williams & Wilkins.

Berthouze, S. E., Minaire, P. M., Castells, J., Busso, T., Vico, L., & Lacour, J. R. (1995). Relationship between mean habitual daily energy expenditure and maximal oxygen uptake. Medicine & Science in Sports & Exercise, 27(8), 1170-1179.

Blair, S. N., Kampert, J. B., Kohl, H. W., 3rd, Barlow, C. E., Macera, C. A., Paffenbarger, R. S., Jr., & Gibbons, L. W. (1996). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. Jama, 276(3), 205-210.

Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 1(8476), 307-310.

Bohannon, R. W. (1997). Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age & Ageing, 26(1), 15-19.

Booth, M. (2000). Assessment of physical activity: an international perspective. Research Quarterly for Exercise & Sport, 71(2 Suppl), S114-120.

Booth, S., & Adams, L. (2001). The shuttle walking test: a reproducible method for evaluating the impact of shortness of breath on functional capacity in patients with advanced cancer. Thorax, 56(2), 146-150.

Borg, G. (1998). Borg's perceived exertion and pain scales. Champaign, IL: Human Kinetics.

Buskirk, E. R., & Hodgson, J. L. (1987). Age and aerobic power: the rate of change in men and women. Federation Proceedings, 46(5), 1824-1829.

Casas, A., Vilaro, J., Rabinovich, R., Mayer, A. F., Antoneli, R., Valera, J. L., Barbera, J. A., Rodriguez-Roisin, R., & Roca, J. (2002). Physiological responses during four clinical exercise protocola in COPD patients. from: Poster session presented at the European Respiratory Society 12th Annual Congress, Stockholm. [Online]. Available: http://www.ersnetsecure.org/public/prg_congres.abstract?ww_i_presentation=6735 [2002, November 10]

Cauley, J. A., LaPorte, R. E., Sandler, R. B., Schramm, M. M., & Kriska, A. M. (1987). Comparison of methods to measure physical activity in postmenopausal women. American Journal of Clinical Nutrition, 45(1), 14-22.

Coughlin, S. S. (1990). Recall bias in epidemiologic studies. Journal of Clinical Epidemiology, 43(1), 87-91.

Cunningham, D. A., Paterson, D. H., Koval, J. J., & St Croix, C. M. (1997). A model of oxygen transport capacity changes for independently living older men and women. Canadian Journal of Applied Physiology, 22(5), 439-453.

Cunningham, D. A., Rechnitzer, P. A., Pearce, M. E., & Donner, A. P. (1982). Determinants of self-selected walking pace across ages 19 to 66. Journal of Gerontology, 37(5), 560-564.

Drinkwater, B. L., Horvath, S. M., & Wells, C. L. (1975). Aerobic power of females, ages 10 to 68. Journal of Gerontology, 30(4), 385-394.

Dyer, C. A., Singh, S. J., Stockley, R. A., Sinclair, A. J., & Hill, S. L. (2002). The incremental shuttle walking test in elderly people with chronic airflow limitation. Thorax, 57(1), 34-38.

Egger, G., Champion, N., & Bolton., A. (1998). The fitness leader's handbook (4th ed. ed.). Kenthurst, N.S.W.: Kangaroo Press.

Fitzgerald, M. D., Tanaka, H., Tran, Z. V., & Seals, D. R. (1997). Age-related declines in maximal aerobic capacity in regularly exercising vs. sedentary women: a meta-analysis. Journal of Applied Physiology, 83(1), 160-165.

Fleg, J. L., & Lakatta, E. G. (1988). Role of muscle loss in the age-associated reduction in VO2 max. Journal of Applied Physiology, 65(3), 1147-1151.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. Medicine & Science in Sports & Exercise, 30(5), 777-781.

Freedson, P. S., & Miller, K. (2000). Objective monitoring of physical activity using motion sensors and heart rate. Research Quarterly for Exercise & Sport, 71(2 Suppl), S21-29.

Froelicher, V. F., Brammell, H., Davis, G., Noguera, I., Stewart, A., & Lancaster, M. C. (1974). A comparison of the reproducibility and physiologic response to three maximal treadmill exercise protocols. Chest, 65(5), 512-517.

Froelicher, V. F., Thompson, A. J., Davis, G., Stewart, A. J., & Triebwasser, J. H. (1975). Prediction of maximal oxygen consumption. Comparison of the Bruce and Balke treadmill protocols. Chest, 68(3), 331-336.

Gibbons, R. J., Balady, G. J., Beasley, J. W., Bricker, J. T., Duvernoy, W. F., Froelicher, V. F., Mark, D. B., Marwick, T. H., McCallister, B. D., Thompson, P. D., Jr., Winters, W. L., Yanowitz, F. G., Ritchie, J. L., Cheitlin, M. D., Eagle, K. A., Gardner, T. J., Garson, A., Jr., Lewis, R. P., O'Rourke, R. A., & Ryan, T. J. (1997). ACC/AHA Guidelines for Exercise Testing. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). Journal of the American College of Cardiology, 30(1), 260-311.

Gibbons, W. J., Fruchter, N., Sloan, S., & Levy, R. D. (2001). Reference values for a multiple repetition 6-minute walk test in healthy adults older than 20 years. Journal of Cardiopulmonary Rehabilitation, 21(2), 87-93.

Goran, M., Fields, D. A., Hunter, G. R., Herd, S. L., & Weinsier, R. L. (2000). Total body fat does not influence maximal aerobic capacity. International Journal of Obesity & Related Metabolic Disorders, 24(7), 841-848.

Green, D. J., Watts, K., Rankin, S., Wong, P., & O' Driscoll, J. G. (2001). A comparison of the Shuttle and 6 Minute Walking Test with measured Peak Oxygen Consumption in patients with Heart Failure. Journal of Science and Medicine in Sport, 4(3), 292-300.

Green, H. J., & Patla, A. E. (1992). Maximal aerobic power: neuromuscular and metabolic considerations. Medicine and science in sports and exercise, 24(1), 38-46.

Green, R. H., Singh, S. J., Williams, J., & Morgan, M. D. (2001). A randomised controlled trial of four weeks versus seven weeks of pulmonary rehabilitation in chronic obstructive pulmonary disease. Thorax, 56(2), 143-145.

Guyatt, G. H., Pugsley, S. O., Sullivan, M. J., Thompson, P. J., Berman, L., Jones, N. L., Fallen, E. L., & Taylor, D. W. (1984). Effect of encouragement on walking test performance. Thorax, 39(11), 818-822.

Haddock, B. L., Hopp, H. P., Mason, J. J., Blix, G., & Blair, S. N. (1998). Cardiorespiratory fitness and cardiovascular disease risk factors in postmenopausal women. Medicine & Science in Sports & Exercise, 30(6), 893-898.

Hamilton, A. L., Killian, K. J., Summers, E., & Jones, N. L. (1996). Symptom intensity and subjective limitation to exercise in patients with cardiorespiratory disorders. Chest, 110(5), 1255-1263.

Hartung, G. H., Blancq, R. J., Lally, D. A., & Krock, L. P. (1995). Estimation of aerobic capacity from submaximal cycle ergometry in women. Medicine & Science in Sports & Exercise, 27(3), 452-457.

Hernandez, M. T., Rubio, T. M., Ruiz, F. O., Riera, H. S., Gil, R. S., & Gomez, J. C. (2000). Results of a home-based training program for patients with COPD. Chest, 118(1), 106-114.

Himann, J. E., Cunningham, D. A., Rechnitzer, P. A., & Paterson, D. H. (1988). Age-related changes in speed of walking. Medicine & Science in Sports & Exercise, 20(2), 161-166.

Holly, R., & Shaffrath, J. (2001). Cardiorespiratory endurance. In J. Roitman (Ed.), ACSM's resource manual for guidelines for exercise testing and prescripion. Baltimore, Maryland: Lippincott Williams & Wilkins.

Hossack, K. F., & Bruce, R. A. (1982). Maximal cardiac function in sedentary normal men and women: comparison of age-related changes. Journal of Applied Physiology: Respiratory, Environmental & Exercise Physiology, 53(4), 799-804.

Huang, Y., Macera, C. A., Blair, S. N., Brill, P. A., Kohl, H. W., & Kronenfeld, J. J. (1998). Physical fitness, physical activity, and functional limitation in adults aged 40 and older. Medicine & Science in Sports & Exercise, 30(9), 1430-1435.

Hunter, G. R., Weinsier, R. L., McCarthy, J. P., Enette Larson-Meyer, D., & Newcomer, B. R. (2001). Hemoglobin, muscle oxidative capacity, and VO2max in African-American and Caucasian women. Medicine & Science in Sports & Exercise, 33(10), 1739-1743.

Jackson, A. S., Wier, L. T., Ayers, G. W., Beard, E. F., Stuteville, J. E., & Blair, S. N. (1996). Changes in aerobic power of women, ages 20-64 yr. Medicine & Science in Sports & Exercise, 28(7), 884-891.

Jacobs, D. R., Jr., Ainsworth, B. E., Hartman, T. J., & Leon, A. S. (1993). A simultaneous evaluation of 10 commonly used physical activity questionnaires. Medicine & Science in Sports & Exercise, 25(1), 81-91.

Kallinen, M., Suominen, H., Vuolteenaho, O., & Alen, M. (1998). Effort tolerance in elderly women with different physical activity backgrounds. Medicine & Science in Sports & Exercise, 30(1), 170-176.

Keell, S. D., Chambers, J. S., Francis, D. P., Edwards, D. F., & Stables, R. H. (1998). Shuttle-walk test to assess chronic heart failure. Lancet, 352(9129), 705.

Kriketos, A. D., Sharp, T. A., Seagle, H. M., Peters, J. C., & Hill, J. O. (2000). Effects of aerobic fitness on fat oxidation and body fatness. Medicine & Science in Sports & Exercise, 32(4), 805-811.

Lakatta, E. G. (1993). Cardiovascular regulatory mechanisms in advanced age. Physiological Reviews, 73(2), 413-467.

Lakka, T. A., Venalainen, J. M., Rauramaa, R., Salonen, R., Tuomilehto, J., & Salonen, J. T. (1994). Relation of leisure-time physical activity and cardiorespiratory fitness to the risk of acute myocardial infarction. New England Journal of Medicine, 330(22), 1549-1554.

Lamonte, M. J., & Ainsworth, B. E. (2001). Quantifying energy expenditure and physical activity in the context of dose response. Medicine & Science in Sports & Exercise, 33(6 Suppl), S370-378; discussion S419-320.

LaMonte, M. J., Eisenman, P. A., Adams, T. D., Shultz, B. B., Ainsworth, B. E., & Yanowitz, F. G. (2000). Cardiorespiratory fitness and coronary heart disease risk factors: the LDS Hospital Fitness Institute cohort. Circulation, 102(14), 1623-1628.

Levine, B. (2001). Exercise physiology for tthe clinician. In P. D. Thompson (Ed.), Exercise and sport cardiology. Singapore: McGraw Hill International.

Lewis, M. E., Newall, C., Townend, J. N., Hill, S. L., & Bonser, R. S. (2001). Incremental shuttle walk test in the assessment of patients for heart transplantation. Heart, 86(2), 183-187.

Macsween, A., Johnson, N. J., Armstrong, G., & Bonn, J. (2001). A validation of the 10-meter incremental shuttle walk test as a measure of aerobic power in cardiac and rheumatoid arthritis patients. Archives of Physical Medicine & Rehabilitation, 82(6), 807-810.

McGavin, C. R., Gupta, S. P., & McHardy, G. J. (1976). Twelve minute walking test for assessing disability in chronic bronchitis. British Medical Journal, 1, 822-823.

McInnis, K. J., Bader, D. S., Pierce, G. L., & Balady, G. J. (1999). Comparison of cardiopulmonary responses in obese women using ramp versus step treadmill protocols. American Journal of Cardiology, 83(2), 289-291, A287.

McMurray, R. G., Ainsworth, B. E., Harrell, J. S., Griggs, T. R., & Williams, O. D. (1998). Is physical activity or aerobic power more influential on reducing cardiovascular disease risk factors? Medicine & Science in Sports & Exercise, 30(10), 1521-1529.

Melanson, E. L., & Freedson, P. S. (1995). Validity of the Computer Science and Applications, Inc. (CSA) activity monitor. Medicine & Science in Sports & Exercise, 27(6), 934-940.

Morales, F. J., Martinez, A., Mendez, M., Agarrado, A., Ortega, F., Fernandez-Guerra, J., Montemayor, T., & Burgos, J. (1999). A shuttle walk test for assessment of functional capacity in chronic heart failure. American Heart Journal, 138(2 Pt 1), 291-298.

Morales, F. J., Montemayor, T., & Martinez, A. (2000). Shuttle versus six-minute walk test in the prediction of outcome in chronic heart failure. International Journal of Cardiology, 76(2-3), 101-105.

Myers, J., Buchanan, N., Smith, D., Neutel, J., Bowes, E., Walsh, D., & Froelicher, V. F. (1992). Individualized ramp treadmill. Observations on a new protocol. Chest, 101(5 Suppl), 236S-241S.

Myers, J., & Froelicher, V. F. (1990). Optimizing the exercise test for pharmacological investigations. Circulation, 82(5), 1839-1846.

Myers, J., & Madhavan, R. (2001). Exercise testing with gas exchange analysis. Cardiology Clinics, 19(3), 433-445.

Oberg, T., Karsznia, A., & Oberg, K. (1993). Basic gait parameters: reference data for normal subjects, 10-79 years of age. Journal of Rehabilitation Research & Development, 30(2), 210-223.

Ogawa, T., Spina, R. J., Martin, W. H., Kohrt, W. M., Schechtman, K. B., Holloszy, J. O., & Ehsani, A. A. (1992). Effects of aging, sex, and physical training on cardiovascular responses to exercise. Circulation, 86(2), 494-503.

Pandolf, K. B. (1982). Differentiated ratings of perceived exertion during physical exercise. Medicine & Science in Sports & Exercise, 14(5), 397-405.

Pankoff, B. A., Hobby, K. J., Lucy, S. D., & Overend, T. J. (2002). Reliability and reproducibility of the shuttle walk test in people with fibromyalgia. Arthritis and Rheumatism, 44(9), S389.

Payne, G. E., & Skehan, J. D. (1996). Shuttle walking test: a new approach for evaluating patients with pacemakers. Heart, 75(4), 414-418.

Pina, I. L., Balady, G. J., Hanson, P., Labovitz, A. J., Madonna, D. W., & Myers, J. (1995). Guidelines for clinical exercise testing laboratories. A statement for healthcare professionals from the Committee on Exercise and Cardiac Rehabilitation, American Heart Association. Circulation, 91(3), 912-921.

Pollock, M. L., Foster, C., Schmidt, D., Hellman, C., Linnerud, A. C., & Ward, A. (1982). Comparative analysis of physiologic responses to three different maximal graded exercise test protocols in healthy women. American Heart Journal, 103(3), 363-373.

Pratt, R. K., Fairbank, J. C., & Virr, A. (2002). The reliability of the Shuttle Walking Test, the Swiss Spinal Stenosis Questionnaire, the Oxford Spinal Stenosis Score, and the Oswestry Disability Index in the assessment of patients with lumbar spinal stenosis. Spine, 27(1), 84-91.

Profant, G. R., Early, R. G., Nilson, K. L., Kusumi, F., Hofer, V., & Bruce, R. A. (1972). Responses to maximal exercise in healthy middle-aged women. Journal of Applied Physiology, 33(5), 595-599.

Revill, D. A., Reynolds, D., Drummond, C., Noor, Z., & Ward, M. J. (2002). Symptom limitation during shuttle walk tests in moderate and sever COPD, from: Poster session presented at the European Respiratory Society 12th Annual Congress, Stockholm. [Online]. Available: http://www.ersnetsecure.org/public/prg_congres.abstract?ww_i_presentation=5515 [2002, November 10]

Richardson, M. T., Ainsworth, B. E., Jacobs, D. R., & Leon, A. S. (2001). Validation of the Stanford 7-day recall to assess habitual physical activity. Annals of Epidemiology, 11(2), 145-153.

Robertson, R. J., Gillespie, R. L., McCarthy, J., & Rose, K. D. (1979). Differentiated perceptions of exertion: part I. mode of integration of regional signals. Perceptual & Motor Skills, 49(3), 683-689.

Sadaria, K. S., & Bohannon, R. W. (2001). The 6-minute walk test: a brief review of literature. Clinical exercise physiology, 3(3), 127-132.

Sallis, J. F., Haskell, W. L., Wood, P. D., Fortmann, S. P., Rogers, T., Blair, S. N., & Paffenbarger, R. S., Jr. (1985). Physical activity assessment methodology in the Five-City Project. American Journal of Epidemiology, 121(1), 91-106.

Seven-day physical activity recall. (1997). Medicine and science in sports and exercise, 29(6 Suppl), S89-S103.

Singh, S. J. (1992). The use of field walking tests for assessment of functional capacity in patients with chronic airways obstruction. Physiotherapy, 78(2), 102-104.

Singh, S. J., Morgan, D. L., & Hardman, A. E. (n.d.). The shuttle walking test. [Instruction booklet]. (Available from Department of Respiratory Medicine The Glenfield Hospital, Leicester, LE3 9QP)

Singh, S. J., Morgan, M. D., Hardman, A. E., Rowe, C., & Bardsley, P. A. (1994). Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. European Respiratory Journal, 7(11), 2016-2020.

Singh, S. J., Morgan, M. D., Scott, S., Walters, D., & Hardman, A. E. (1992). Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax, 47(12), 1019-1024.

Singh, S. J., Smith, D. L., Hyland, M. E., & Morgan, M. D. (1998). A short outpatient pulmonary rehabilitation programme: immediate and longer-term effects on exercise performance and quality of life. Respiratory Medicine, 92(9), 1146-1154.

Singh, S. J., Sodergren, S. C., Hyland, M. E., Williams, J., & Morgan, M. D. (2001). A comparison of three disease-specific and two generic health-status measures to evaluate the outcome of pulmonary rehabilitation in COPD. Respiratory Medicine, 95(1), 71-77.

Solway, S., Brooks, D., Lacasse, Y., & Thomas, S. (2001). A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest, 119(1), 256-270.

Steele, B. (1996). Timed walking tests of exercise capacity in chronic cardiopulmonary illness. Journal of Cardiopulmonary Rehabilitation, 16(1), 25-33.

Stevenson, E. T., Davy, K. P., & Seals, D. R. (1994). Maximal aerobic capacity and total blood volume in highly trained middle-aged and older female endurance athletes. Journal of Applied Physiology, 77(4), 1691-1696.

Stofan, J. R., DiPietro, L., Davis, D., Kohl, H. W., 3rd, & Blair, S. N. (1998). Physical activity patterns associated with cardiorespiratory fitness and reduced mortality: the Aerobics Center Longitudinal Study. American Journal of Public Health, 88(12), 1807-1813.

Talbot, L. A., Metter, E. J., & Fleg, J. L. (2000). Leisure-time physical activities and their relationship to cardiorespiratory fitness in healthy men and women 18-95 years old. Medicine & Science in Sports & Exercise, 32(2), 417-425.

Tallaj, J. A., Sanderson, B., Breland, J., Adams, C., Schumann, C., & Bittner, V. (2001). Assessment of Functional Outcomes using the 6 Minute Walk Test in Cardiac Rehabilitation: Comparison of patients with and without Left Ventricular Dsyfunction. Journal of Cardiopulmonary Rehabilitation, 21, 221-224.

Tanaka, H., Desouza, C. A., Jones, P. P., Stevenson, E. T., Davy, K. P., & Seals, D. R. (1997). Greater rate of decline in maximal aerobic capacity with age in physically active vs. sedentary healthy women. Journal of Applied Physiology, 83(6), 1947-1953.

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. Journal of the American College of Cardiology, 37(1), 153-156.

Toth, M. J., Gardner, A. W., Ades, P. A., & Poehlman, E. T. (1994). Contribution of body composition and physical activity to age-related decline in peak VO2 in men and women. Journal of Applied Physiology, 77(2), 647-652.

Troosters, T., Gosselink, R., & Decramer, M. (1999). Six minute walking distance in healthy elderly subjects. European Respiratory Journal, 14(2), 270-274.

Trost, S. G., Ward, D. S., Moorehead, S. M., Watson, P. D., Riner, W., & Burke, J. R. (1998). Validity of the computer science and applications (CSA) activity monitor in children. Medicine & Science in Sports & Exercise, 30(4), 629-633.

Wasserman, K., Hansen, J. E., Sue, D. Y., Casaburi, R., & Whipp, B. J. (1999). Principles of exercise testing and interpretation (3rd ed.). Philadelphia: Lea & Febiger.

Webb, H. F., Lawrence, J., Jones, P. R., Singh, S. J., & Morgan, M. D. (2002). Age-related standards for performance in the incremental shuttle walking test: a pilot study in healthy men aged 40-69 years. from: Poster session presented at the European Respiratory Society 12th Annual Congress, Stockholm. [Online]. Available: http://www.ersnetsecure.org/public/prg_congres.abstract?ww_i_presentation=5509 [2002, November 10]

Wells, C. L., Boorman, M. A., & Riggs, D. M. (1992). Effect of age and menopausal status on cardiorespiratory fitness in masters women runners. Medicine & Science in Sports & Exercise, 24(10), 1147-1154.

Appendix A - Informed consent form

Validating the use of Shuttle Walking Test in healthy adult women

INFORMED CONSENT FORM

Thank you for taking your time out to be involved in this research study. Prior to commencement, it is my duty to provide the relevant information so that you can make an informed decision of your wish to participate in this study.

This study will investigate if the shuttle walking test is a useful tool to evaluate physical fitness. The significance of this study will provide exercise physiologists with a cheaper and easier method to measure physical fitness.

You will be required to complete a physical activity questionnaire. You will also be required to wear an activity monitor for a period of seven days. During this period, a diary will be provided so that you can record the details of the activities engaged in during the week. On separate occasions, you will perform a walking test on a treadmill ergometer at a speed you are comfortable with. In addition a separate walking test, which will involve walking to a specific time frame from a pre- recorded tape- will be conducted a week before/ after the treadmill walking test. For the entire study, you will be required to attend 4 one- hourly sessions at the laboratory in Edith Cowan University, Joondalup campus.

As the test aims to establish your maximal levels of fitness, it may be associated with some sense of fatigue or discomfort. For this reason, you will be required to complete a medical history questionnaire and attend a medical screening with your General Practitioner. The university will cover all costs incurred with this examination. You may end any of the test/s at any time and you are free to withdraw from the study at any stage without providing any reasons.

All information obtained will be treated with strict confidentiality. To protect your anonymity, all relevant data will be coded and kept in a secure place under lock and key. No other person/s other than the researcher will be able to access such information.

Should you have further enquiries/ suggestions regarding this study, please do not hesitate to contact either my Project Supervisor or myself. Contact details are as follows: -

(Project Supervisor)
Name: Dr Paul Sacco
Position: Senior Lecturer
Tel (O): (08) 9-400- 5642
Email:**p.sacco@ecu.edu.au**

(Researcher)
Name: Micheal Lim
Position: Honours Student
Tel (O): (08) 9-400-5073
Email: **micheal.lim@ecu.edu.au**

Thank you again!
Yours sincerely,

Micheal Lim
Honours Student
Exercise Physiology
Edith Cowan University

Declaration

I, ________________________________(Name of participant), have read and understood the procedures and risks described above. I acknowledge that any questions asked have been answered to my satisfaction.

I hereby agree to participate in this activity, realising that I have the right to withdraw at any time. I agree that research data gathered for this study may be published provided that confidentiality is maintained.

______________________	____________
Signature of Subject	Date
______________________	____________
Signature of Witness	Date
______________________	____________
Signature of Researcher	Date

Appendix B - Medical history questionnaire

MEDICAL HISTORY QUESTIONNAIRE

(Personal Information)

Name: ____________________

Age (yrs):________ Date of birth: ______

Weight (kg):______ Height (cm): ______

(To be filled by medical practitioner)

Blood pressure: __________ Pulse: ______

Please read each question properly and answer them accurately.

(Family history)

Have you suffered from any of the medical conditions below: -

High Blood Pressure	☐ Yes	☐ No	☐ Not sure
Heart problems	☐ Yes	☐ No	☐ Not sure
Arthritis	☐ Yes	☐ No	☐ Not sure
Emotional problems	☐ Yes	☐ No	☐ Not sure
Diabetes	☐ Yes	☐ No	☐ Not sure
Epilepsy	☐ Yes	☐ No	☐ Not sure
Anaemia	☐ Yes	☐ No	☐ Not sure
Osteoporosis	☐ Yes	☐ No	☐ Not sure
Asthma	☐ Yes	☐ No	☐ Not sure

Others (please name): ________________

(Recent conditions)

Have you recently and/or at present experience any of the conditions below: -

Angina	☐ Yes	☐ No
Heart attack	☐ Yes	☐ No
Shortness of breath	☐ Yes	☐ No
Headaches	☐ Yes	☐ No
Dizziness/ fainting spells	☐ Yes	☐ No
Lose balance or consciousness	☐ Yes	☐ No
Menopause	☐ Yes	☐ No

If Yes (please state Year): __________

Musculoskeletal injuries of any sort (please name): ____________________

Do you currently smoke/ have any history of smoking?

☐ Yes (Please state amount each day): ________ ☐ No

☐ Used to (Please state history and amount): __________

☐ Amount/ History: __________

(Medications)

Are you currently or have been taking any prescribed or non-prescribed medicine/ supplements?

☐ Yes (Please name & state quantity) ☐ No

Medications/ supplements: ______________________________

I, ________________________________(Name), declare that the information provided above is correct and most accurate as of (date).

______________________________ ____________

Signature of Subject **Date**

______________________________ ____________

Signature of Witness **Date**

______________________________ ____________

Signature of Researcher **Date**

Appendix C - Information sheet for general practitioner

Information sheet for General Practitioner

Re: Validation of shuttle walking test in healthy adult women

To the General Practitioner

This is to inform you that ____________________(Name), has expressed interest to be involved as a subject for this study. The study requires the subject to undergo two separate walking tests. They are: -

1) A treadmill Walking Test

Subjects will walk on a treadmill at a constant speed that they are comfortable with. At every minute, gradient will increase by 1% and subjects will walk till they have reached their peak ability.

2) A Shuttle Walking Test

This test will involve walking between two markers, nine meters apart, keeping within a specified time frame from a pre- recorded tape.

For both tests, heart rate, oxygen saturation and rating of perceived exertion will be recorded. In addition, respiratory variables like oxygen consumption will be measured for the treadmill walking test. As the test aims to establish the subject's maximal levels of fitness, it may be associated with some sense of fatigue or discomfort. Nonetheless, subjects are free to terminate the test at any stage and/ or when they display any signs of contraindications of exercise.

To prevent complications during the test, I would like to seek your clearance for this subject to participate in the abovementioned study. Should you have any further queries regarding the study, please do not hesitate to contact me at:

Tel (O): 9400 5073 Email: micheal.lim@ecu.edu.au

Thank you!

Yours truly,

Micheal Lim

Edith Cowan University

Comments:

____

____

____

____

Declaration

I, ______________________(Name of doctor) certify that I have read the requirements of the test. I have examined ____________________ (Name of subject) and hereby certify her fit/ unfit for the abovementioned test.

________________________ ____________

Signature of doctor Date

Appendix D - Borg's Category Ratio (CR10) Scale

0	**Nothing at all**	**"No P"**
0.5	**Extremely weak**	**Just noticeable**
1	**Very weak**	
2	**Weak**	**Light**
3	**Moderate**	
4		
5	**Strong**	**Heavy**
6		
7	**Very strong**	
8		
9		
10	**Extremely strong**	**"Max P"**
11		
●	**Absolute maximum**	**Highest possible**

Adapted from Borg (1998, p.50)

Appendix E - Seven day recall (7DR)

Subject ID: ____________________ Day: _______ Date: _______

Interviewer: ____________________ *PAR# 1 2 3*

1. Were you employed in the last seven days?
   No (Skip to Q#4) Yes
2. How many days of the last seven did you work? ________________ Days
3. How many total hours did you work in the last seven days? ______Hrs
4. What two days do you consider your weekend days?
   ______ ______ *(Mark weekend days below with a circle)*

		Days						
		1	*2*	*3*	*4*	*5*	*6*	*7*
	Sleep							
Morning	*Moderate*							
	Hard							
	Very hard							
Afternoon	*Moderate*							
	Hard							
	Very hard							
Evening	*Moderate*							
	Hard							
	Very hard							
Total Min	*Strength*							
Per day	*Flexibility*							

4a. Compared to your physical activity over the past three months, was last week's physical activity more, less or about the same? 1. More 2. Less 3. About the same

Worksheet key:	Rounding:		
	10 – 22 min	=	0.25
An asterisk (*) denotes a work-related activity.	23 – 37 min	=	0.50
A circle denotes a weekend day.	38 – 52 min	=	0.75
	53 – 1: 07 hr/ min	=	1.0
	1:08 – 1:22 hr/min	=	1.25

(INTERVIEWER)

Please answer questions below and note any comments on interview.

5. Were there any problems with the Seven-Day PAR interview?

   0. No 1. Yes (If yes, please explain.)

   ____

   ____

   ____

6. Do you think this was a valid Seven-Day PAR interview

   0. No 1. Yes

7. Please lsit below any activities reported by the subject which you don't know how to classify.

   ____

   ____

   ____

8. Please provide any other comments you may have in the space below.

   ____

   ____

   ____

Adapted from (Seven-day physical activity recall, 1997)

Appendix F – Reliability of 7DR-Total

Analysis: One way ANOVA with repeated measures

Description	Value
P value	0.3795
P value summary	ns
Are means signif. different? (P < 0.05)	No
Number of groups	3
F	0.9955
R squared	0.05241

ANOVA Table	SS	df	MS
Treatment (between columns)	5419	2	2709
Individual (between rows)	209500	18	11640
Residual (random)	97980	36	2722
Total	312900	56	

Tukey's Multiple Comparison Test	Mean Diff.	q	P value	95% CI of diff
Recall 1 vs Recall 2	8.459	0.7068	P > 0.05	-32.95 to 49.86
Recall 1 vs Recall 3	23.57	1.97	P > 0.05	-17.83 to 64.98
Recall 2 vs Recall 3	15.11	1.263	P > 0.05	-26.29 to 56.52

Appendix G – Individual subject's data

Individual results for Individual Balke Test (IBT)

Subject	$\dot{V}O_{2peak}$ ($L.min^{-1}$)	$\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$)	$\dot{V}E$ ($L.min^{-1}$)	RER	HR_{peak} (bpm)	SpO_{2peak} (%)	RPE-C	RPE-P
1	1.67	26.0	56.1	1.12	108	92	6	7
2	1.57	23.9	42.1	1.01	154	96	7	6
3	2.15	39.0	58.9	1.20	164	97	3	3
4	2.05	26.5	69.1	1.35	180	-	9	9
5	2.12	36.8	73.1	1.14	172	97	5	5
6	2.34	43.7	85.2	1.23	172	-	9	8
7	1.78	27.9	64.2	1.31	148	96	10	10
8	1.51	26.0	60.6	1.34	190	97	4	3
9	1.33	22.7	56.8	1.35	172	97	9	10
10	1.20	18.2	48.5	1.25	169	97	5	4
11	2.12	43.3	73.4	1.23	185	77	10	10
12	2.55	29.9	93.4	1.22	167	96	6	7
13	1.45	22.1	43.1	1.20	162	94	8	9
14	1.74	22.8	72.7	1.46	181	95	7	9
15	1.45	27.6	55.3	1.37	174	92	5	7
16	1.47	25.8	47.1	1.16	126	-	9	9
17	1.30	23.1	56.3	1.32	179	98	9	8
18	1.35	24.7	51.5	1.25	151	98	5	5
19	1.43	24.8	40.8	1.04	145	97	5	3
20	2.34	47.0	79.9	1.28	188	99	10	9
21	1.59	23.2	56.8	1.12	152	97	1	1
22	1.75	22.4	62.6	1.48	187	96	3	4
23	2.10	29.4	90.7	1.31	136	89	8	8
24	1.93	23.6	75.5	1.39	157	94	5	5
25	1.99	27.3	73.9	1.21	172	95	4	1
26	2.07	26.5	61.8	1.14	179	-	9	9
27	2.56	34.4	78.4	1.24	179	96	5	6
28	1.63	29.1	49.0	1.23	188	96	10	10
29	2.09	32.3	79.4	1.30	177	97	9	7
30	2.07	28.0	73.1	1.31	171	95	4	4
31	1.58	24.9	57.8	1.29	169	-	5	4
32	2.01	37.6	72.9	1.33	189	-	10	10
33	2.21	29.0	62.9	1.27	162	95	4	4
34	2.30	50.5	78.8	1.15	177	95	6	8
n	34							
Mean	1.8	29.4	64.8	1.25	167	95	6.6	6.5
SEM	0.1	1.3	2.4	0.0	3.2	0.7	0.4	0.5
SD	0.4	7.8	13.9	0.1	18.7	4.1	2.5	2.7
Min	1.20	18.2	40.8	1.01	108	77	1.0	1.0
Max	2.56	50.5	93.4	1.48	190	99	10.0	10.0

Individual results for Shuttle Walk Test (SWT)

Subject	SWT distance (m)	HR_{peak} (bpm)	SpO_{2peak} (%)	RPE-C	RPE-P
1	430	93	90	2.0	2.0
2	570	153	96	3.0	3.0
3	620	158	96	3.0	4.0
4	620	125	97	1.0	1.0
5	640	105	95	2.0	1.0
6	420	98	97	0.5	0.5
7	450	127	70	3.0	0.5
8	640	128	96	6.0	7.0
9	450	116	97	3.0	3.0
10	1020	174	83	6.0	6.0
11	540	128	95	2.0	2.5
12	460	103	97	2.0	2.0
13	840	175	-	1.0	2.0
14	770	162	95	6.0	6.0
15	640	98	91	3.0	2.0
16	670	175	98	3.0	3.0
17	450	124	95	5.0	5.0
18	540	111	-	2.0	1.0
19	810	140	95	4.0	4.0
20	480	126	95	2.0	3.0
21	500	154	94	1.0	0.5
22	560	99	96	0	0.0
23	730	143	96	2.0	3.0
24	450	116	-	0.5	0.5
25	670	158	97	8.0	9.0
26	790	160	-	1.0	3.0
27	690	164	96	4.0	5.0
28	800	149	100	4.0	4.0
29	610	143	94	4.0	5.0
30	540	118	93	1.0	0.5
31	560	124	-	1.0	1.0
32	750	149	91	3.0	3.0
33	900	151	98	4.0	4.0
n	33				
Mean	624.5	134.8	94.0	2.8	2.9
SEM	26.2	4.3	1.0	0.3	0.4
SD	150.7	24.6	5.7	1.9	2.1
Min	420.00	93.0	70.0	0.0	0.0
Max	1020.00	175.0	100.0	8.0	9.0

Appendix H – Student's t-test results

Note: * indicates significant variables

Measurements at peak exercise intensity

Variable	IBP		SWT		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
% A-P HR_{peak}	97.1	2.3	78.4	2.3	10.03	p < 0.0001*
SpO_{2rest} (%)	97.1	0.3	97.8	0.2	2.397	0.025*
SpO_2 (%)	95.0	0.8	94.0	1.1	1.558	0.134
$\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$)	29.4	1.3	-	-	-	-
$\dot{V}O_{2peak}$ ($L.min^{-1}$)	1.8	0.1	-	-	-	-
$\dot{V}E$ ($L.min^{-1}$)	64.8	2.4	-	-	-	-
RER	1.3	0.0	-	-	-	-
METs	8.4	0.4	-	-	-	-
RPE-C	6.6	0.4	2.8	0.3	8.084	p < 0.0001*
RPE-P	6.5	0.5	2.9	0.4	7.953	p < 0.0001*
Stage	10.4	0.7	8.6	0.2	6.346	p < 0.0001*
Speed (mph)	3.0	0.1	-	-	-	-

Heart rate (bpm) response during exercise

Variable	IBT		SWT		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
Rest	74.2	1.7	74.3	1.9	0.785	0.275
Warmup	105	2.8	96	2.3	3.03	0.0049*
Start	104	4.1	85	1.9	9.439	p < 0.0001*
Mid	135	4.1	102	2.3	13.05	p < 0.0001*
End	167.1	4.8	134.8	4.3	5.921	p < 0.0001*
Recovery	118	2.5	93	3.1	7.86	p < 0.0001*

Difference between RPE-C and RPE-P

Variable	RPE-C		RPE-P		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
IBT	6.6	0.4	6.5	0.5	0.305	0.763
SWT	2.8	0.3	2.9	0.4	0.849	0.402

RPE-C at start at mid of exercise

Variable	IBT		SWT		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
Start	0.4	0.1	0.2	0.1	4.045	0.0003*
Mid	2.3	0.3	0.7	0.2	6.823	p < 0.0001*

RPE-P at start at mid of exercise

Variable	IBT		SWT		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
Start	0.5	0.1	0.1	0.1	4.086	0.0003*
Mid	2.5	0.3	0.5	0.2	7.884	p < 0.0001*

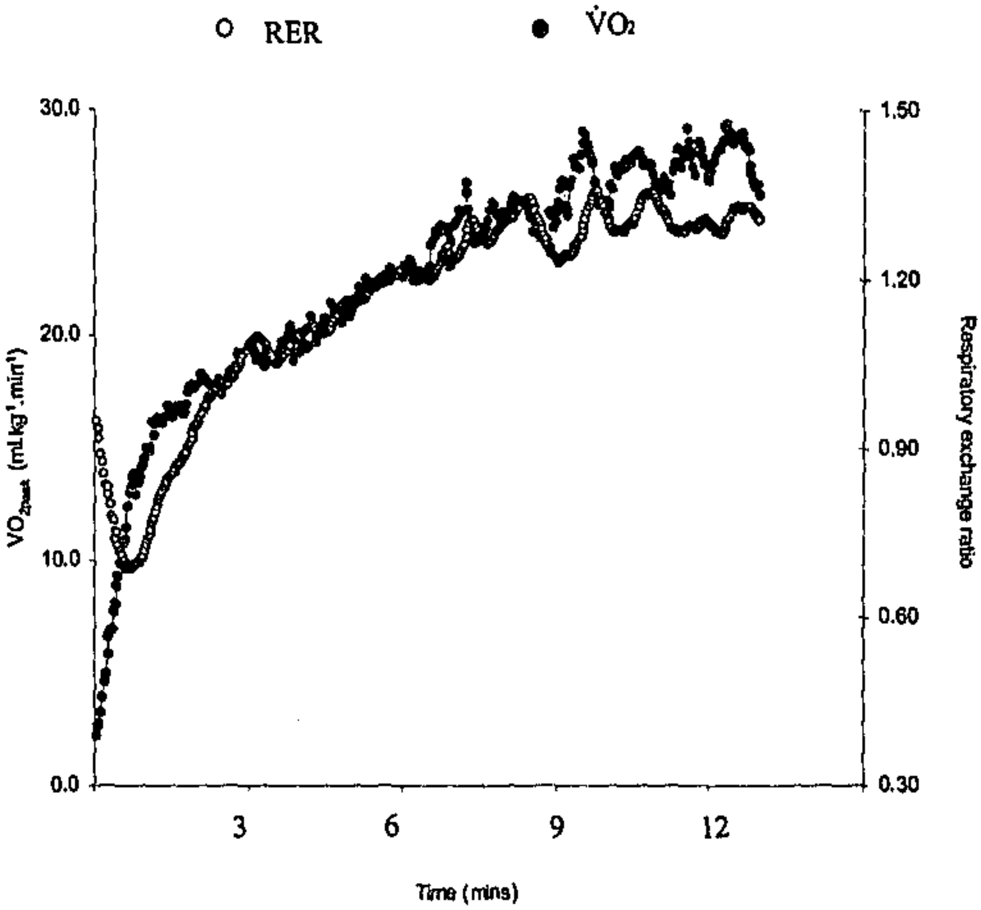
Habitual physical activity between instruments

Variable	CSA			7DR		
($MET.min.d^{-1}$)	t	p		t	p	
Total	2.388	0.0316	*	2.7	0.0187	*
Rest	2.388	0.0316	*	2.7	0.0187	*
Light	2.61	0.0206	*	1.2	0.2487	ns
Moderate	0.071	0.9445	ns	0.3	0.7743	ns
Hard	2.527	0.0242	*	0.2	0.8114	ns
Very hard	-	-	ns	-	-	ns
n	6					

Difference in selected variables between age group

Variable	31 – 40 yrs		≥ 61 yrs		Student's Paired t - test	
	Mean	SEM	Mean	SEM	t	p (two-tailed)
Age (yrs)	36.2	0.7	62.5	0.4	31.16	p < 0.0001*
Est. BF(%)	28.4	2.3	40.6	2.8	3.375	0.003*
Est. FFM (kg)	44.2	1.9	37.78	1.8	2.429	0.026*
vo2peak	2.1	0.1	1.6	0.1	3.855	0.001*
SWT distance (m)	702.0	51.8	559.0	38.5	2.215	0.039*

Appendix I – Example of $\dot{V}O_2$ response



An example of a $\dot{V}O_2$ response is shown above. The data belongs to one of the subjects who achieved a $\dot{V}O_{2peak}$ similar to that shown in the group mean (29.4 ± 1.3). Note the $\dot{V}O_2$ plateau and high RER (~ 1.30) at the final minute of exercise.