The Generalizability of Treadmill to Overground Measures of Oxygen Uptake and the Efficacy of the American College of Sports Medicine Prediction Equation in Older Women

BY

WILLIAM M. BRENNAN

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  - Finance 0508
  - History 0509
  - Labor 0510
  - Theory 0511
- Folklore 0358
- Geography 0366
- Gerontology 0351
- History
  - General 0578
  - Ancient 0579
  - Medieval 0581
  - Modern 0582
  - Black 0328
  - African 0331
  - Asia, Australia and Oceania 0332
  - Canadian 0334
  - European 0335
  - Latin American 0336
  - Middle Eastern 0333
  - United States 0337
- History of Science 0585
- Law 0398
- Political Science
  - General 0615
  - International Law and Relations 0616
  - Public Administration 0617
- Recreation 0814
- Social Work 0452
- Sociology
  - General 0626
  - Criminology and Penology 0627
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  - Public and Social Welfare 0630
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  - Biostatistics 0308
  - Botany 0309
  - Cell 0379
  - Ecology 0329
  - Entomology 0353
  - Genetics 0369
  - Limnology 0793
  - Microbiology 0410
  - Molecular 0307
  - Neuroscience 0317
  - Oceanography 0416
  - Physiology 0433
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- Biophysics
  - General 0786
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  - Immunology 0982
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  - Obstetrics and Gynecology 0380
  - Occupational Health and Therapy 0354
  - Ophthalmology 0381
  - Pathology 0571
  - Pharmacology 0419
  - Pharmacy 0572
  - Physical Therapy 0382
  - Public Health 0573
  - Radiology 0574
  - Recreation 0575
  - Speech Pathology 0460
  - Toxicology 0383
- Home Economics 0386

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  - Polymer 0495
  - Radiation 0754
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  - General 0605
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  - Atmospheric Science 0608
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  - Electronics and Electricity 0607
  - Elementary Particles and High Energy 0798
  - Fluid and Plasma 0759
  - Molecular 0609
  - Nuclear 0610
  - Optics 0752
  - Radiation 0756
  - Solid State 0611
- Statistics 0463

Applied Sciences

- Applied Mechanics 0346
- Computer Science 0984
- Engineering
  - General 0537
  - Aerospace 0538
  - Agricultural 0539
  - Automotive 0540
  - Biomedical 0541
  - Chemical 0542
  - Civil 0543
  - Electronics and Electrical 0544
  - Heat and Thermodynamics 0348
  - Hydraulic 0545
  - Industrial 0546
  - Marine 0547
  - Materials Science 0794
  - Mechanical 0548
  - Metallurgy 0743
  - Mining 0551
  - Nuclear 0552
  - Packaging 0549
  - Petroleum 0765
  - Sanitary and Municipal 0554
  - System Science 0790
- Geotechnology 0428
- Operations Research 0796
- Plastics Technology 0795
- Textile Technology 0994

PSYCHOLOGY

- General 0621
- Behavioral 0384
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THE GENERALIZABILITY OF TREADMILL TO OVERGROUND MEASURES OF OXYGEN UPTAKE AND THE EFFICACY OF THE AMERICAN COLLEGE OF SPORTS MEDICINE PREDICTION EQUATION IN OLDER WOMEN

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TABLE OF CONTENTS

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ABSTRACT

To assess the contribution of low intensity "lifestyle activities" in the lowering of certain risk factors for cardiovascular disease, quantification of the oxygen cost of the activity is essential. Although direct measurement through the analysis of gas exchange variables is the most accurate means of assessing the oxygen cost of a given activity, it is labor intensive and cost prohibitive. Consequently, tests using motor-driven treadmills and mathematical models predicting the oxygen requirements of various activities have become commonplace in field studies employing large sample sizes. The purpose of this study was to determine, in a population of elderly women, the relationship between the oxygen cost during steady state treadmill and track walking at the same velocities and to compare those values to values predicted from a commonly used equation developed by the American College of Sports Medicine. Though the ACSM equation for predicting oxygen uptake during horizontal walking is widely accepted, it does not make adjustments for changes associated with the aging process. Ten women over the age of 59 (average = 65.4 years) performed two steady state walking tests at 50% heart rate reserve, on both the track and the treadmill. The repeatability of the track and treadmill oxygen uptake measures was assessed on two successive occasions. Both the track and treadmill tests were found to be repeatable with no significant differences in VO_2 or HR found between the first and second tests. Although both protocols were repeatable, measures on the treadmill disclosed less between trial variability, thus more stability, albeit insignificant. The ACSM equation significantly under predicted the

VO_2 in older women and thus was not valid in this population. These results indicate that factors not considered by the ACSM equation, such as fat free mass also influence VO_2 in the aging female. The model developed by the present study to predict the oxygen cost of horizontal steady state walking is as follows:

Pred. $VO_2 = 20.203 + 3.014 \bullet V_{TM} - 0.407 \bullet FFM$ (SEE=1.74) where, Pred. VO_2 = ACSM predicted VO_2, V_{TM} = treadmill walking velocity and FFM = fat free mass.

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Oxygen consumption for a given activity can be directly measured through gas exchange variables, or predicted through a mathematical model. Collecting and analyzing expired gases during the activity and calculating the relative concentrations of oxygen and carbon dioxide is the most accurate means of assessing the oxygen requirements of an activity (Appendix #1). This method is, however, labor intensive and requires equipment that is both cumbersome and expensive. In field studies using large populations it would consequently be difficult to obtain oxygen uptake measures. As a result the motor-driven treadmill is frequently used to simulate overground walking in biomechanical and exercise physiological studies where standardized, reproducible results are desirable (Bassett, Giese, Nable, Ward, Raab & Balke, 1985; Van Ingen Schenau, 1980; Nelson, Dillman, Lagasse & Bickett, 1972).

External validity or the ability to extrapolate treadmill measurements to equivalent measures overground, is at present a debatable issue (Van Ingen Schenau, 1980; Arsenault, 1986). Even though differences may exist between the oxygen cost of overground versus treadmill walking, these may be outweighed by the treadmill's safety, ease of use, convenience and the capacity to acquire measurements while walking at a predetermined speed and grade (Wall & Charteris, 1981). It is necessary to establish whether differences exist between the treadmill and overground environments, whether these differences are outweighed by the convenience of utilizing a motor-driven treadmill and additionally, whether testing on a motor driven treadmill is repeatable in populations such as the elderly who demonstrate altered patterns of gait.

Although low intensity "lifestyle activities" such as walking demonstrate a less pronounced effect on cardiovascular fitness, they are beneficial for cardiovascular risk profiles (Foster & Thompson, 1991). To assess the contribution of low to moderate activities, such as walking, to the lowering of certain risk factors for cardiovascular disease, quantification of the oxygen cost of the activity is essential. The oxygen uptake of a given activity is often predicted from a mathematical model in field studies or in investigations that employ large sample sizes. The interdependence of oxygen uptake on walking velocity enables prediction of oxygen uptake through regression equations, however, any factors or combination of factors affecting the accepted relationships between walking velocity and oxygen uptake would render the regression equation invalid. Age-related functional changes in the cardiovascular and musculoskeletal systems are well documented and adversely affect the oxygen requirement of walking therefore causing the ACSM equation to inaccurately reflect the oxygen cost versus workload relationship (Martin & Morgan, 1991). The presence of age-related changes in oxygen uptake kinetics, gait parameters and/or body composition would also pose questions regarding the validity of prediction equations when aged subjects are utilized. As a result, corrections must be made so a mathematical model can accurately reflect the oxygen cost of walking in an elderly population. (Jankowski, Ferguson, Langelier, Chanoitis & Choquette, 1972).

Statement of the Problem

The purpose of this study was to determine, in a population of elderly women, the relationship between the oxygen uptake during steady state treadmill and track walking at the same velocity and to compare those values to values derived from a commonly used equation developed by the American College of Sports Medicine (ACSM, 1988). Specifically, the women walked on a treadmill and on a track at a velocity that elicited a heart rate of 50% heart rate reserve (HRR). The oxygen cost of steady state walking on both the treadmill and track were compared to estimated oxygen uptake at the same velocity using the ACSM prediction equation. The repeatability of the oxygen uptake measurements on the treadmill and track were also assessed on two successive occasions.

Hypotheses

The following outcomes were hypothesized for this study:

1. Measurement of oxygen uptake on the treadmill would be more repeatable than measures for track walking when tested on repeated measures.

2. The oxygen cost of walking on the treadmill would be less than that expended during walking on the track.

3. The ACSM equation would underestimate the oxygen uptake for elderly subjects during level walking on the track and the treadmill at the same velocity.

Delimitations

The following points should be considered when reviewing this study.

1. The method of selection of subjects in this study was by recruitment rather than random selection. Selection by recruitment increases the chance of selection bias prejudicing the results. Attempts to minimize selection bias were made by excluding no subjects and by encouraging any participants interested to inquire about the study.

2. Due to the small sample size and the narrow age range of the subjects, results of this study may only be applicable to a similar cohort.

3. Measurements of oxygen uptake were by indirect calorimetry and are thus subject to small margins of measurement error in the gas analysis. Although this was minimized by frequent calibration, the potential for some measurement error was present.

4. Percent fat as estimated using the regression equation of Jackson, Pollock and Ward (1980) cannot be validated in the subjects of this study. Validation would involve the determination of body density by hydrodensiometry and the calculation of percent fat according to the method of Siri (1961).

Definition of Terms

Heart Rate Reserve

Target heart rate was determined by calculation utilizing the formula of Karvonen, Kentala and Mustala (1957):

HRR = HRmax - HRrest

where:

HRR = heart rate reserve

HRmax = maximal heart rate (220-age)

HRrest = resting heart rate

Target Heart Rate

A heart rate to be obtained during exercise. It is calculated using resting values and for the purposes of this study the following equation was utilized:

$THR = .50 \bullet HRR + HRrest$

where:

THR = target heart rate

HRR = heart rate reserve from above

Open Circuit Spirometry

Oxygen consumption or oxygen uptake is determined by collecting and analyzing expired gases and comparing the relative concentrations with known constants of inspired ambient air which are: oxygen = 20.93%, carbon dioxide = 0.03% and nitrogen = 79.04%. Since oxygen is the currency during metabolic work and carbon dioxide is produced, the exhaled air contains less oxygen and more carbon dioxide than the inhaled air.

Douglas Bag

An extensible plastic bag used for collection of expired gas.

Steady State

Pertaining to the time period during which a physiological function (such as heart rate) remains at a plateau or constant value ($\pm$ 2.5 bpm).

Oxygen Uptake

Oxygen consumed to perform physical work. This reflects the rate of expired gas and the difference between inspired ambient air and expired air.

Oxygen Transport System

Composed of the stroke volume (SV), the heart rate (HR), and the arterial-mixed venous oxygen difference ($a\text{-}\bar{v}\ O_2$ diff.). Mathematically defined by the following:

$$VO_2 = SV \bullet HR \bullet a\text{-}\bar{v}\ O_2 \text{ diff.}$$

American College of Sports Medicine Prediction Equation

The prediction equation for the oxygen cost during walking on level ground set forth by the American College of Sports Medicine was utilized in this study and is as follows:

$$VO_2\ (ml \bullet kg^{-1} \bullet min^{-1}) = 0.1\{velocity\ (m \bullet min^{-1})\} + 3.5$$

Chapter 2

REVIEW OF RELATED LITERATURE

General Overview

Regular physical activity is known to be beneficial to general health and fitness in middle-aged and older people, as well as in the young (deVries, 1970; Leaf, Parker & McAfee, 1989). There is a general consensus that vigorous exercise is a useful preventive measure for various coronary artery disease risk factors (Hagberg, 1991; Sallis, Haskell, Fortmann, Wood & Vranizan, 1986; Brownell, Bachorik & Ayerle, 1982). The extent of this attenuated risk is believed to be associated with the intensity and duration of the exercise program (Cunningham, Rechnitzer & Donner, 1986).

Intense exercise such as running may not be achievable in an elderly population due to age-related functional changes, thus an exercise regimen must employ low intensity lifestyle activities (Leaf et al., 1989; Cook et al., 1986; Sallis et al., 1986). These activities must be done over a long period of time to elicit the changes in body composition and serum lipids that coincide with a decrease in metabolic risk factors for CVD (Superko, 1991; Cook et al., 1986; Girandola, 1976). Therefore, an ideal program of physical activity would adequately stress the aerobic system, yet minimize the drawbacks associated with high intensity exercise, such as overuse syndromes. Fitness programs and cardiac rehabilitation centers utilizing exercise regimens of moderate intensity have testified that activities of this intensity have favorable effects on body mass, blood pressure and lipoproteins (Leaf et al., 1989; Sallis et al., 1986). It has also been demonstrated that cardiovascular risk may be reduced without large changes in functional capacity through participation chronic low level activity (Cook et al., 1986; Brownell et al., 1982; Girandola, 1976). To properly assess the contribution of low intensity lifestyle activities and to formulate a proper exercise prescription of exercise frequency and duration, it is essential to quantify the oxygen consumed for a given activity (Roy, Grove, Christie, 1992; Inoue, Nakao, Ishizashi & Murakami, 1990). Even though increases in maximal aerobic power may be more easily achieved through high intensity exercise, this may not necessarily translate into advantages over low intensity exercise when considering coronary artery disease risk profile improvements (Girandola, 1976; Sallis et al., 1986). To that end, the volume or amount of oxygen consumed, rather than the rate of oxygen consumption, would appear to be a more suitable parameter to be considered (Roy et al., 1992).

Predicting Oxygen Cost of Walking

Walking is becoming increasingly accepted as a mode of training in programs targeting weight loss and reduction of cardiovascular risk factors. This in turn, has led to a considerable increase in the understanding of the oxygen requirements of walking. To properly prescribe exercise frequency and duration, the oxygen cost of walking must be either measured via gas exchange variables or procured through a prediction equation (Roy et al., 1992). Although gas analysis would undoubtedly be most accurate, the cost of the highly technical equipment necessary has lead to an array of prediction formulas utilizing various predictor variables

(Roy et al., 1992). The predictability of oxygen uptake is premised on the existence of a linear relationship between the oxygen uptake and velocity of walking within a range of 50-100 m/min (Bubb, Martin & Howley, 1985). Although walking velocity is paramount in predicting the oxygen cost of walking, speed alone is not a unique indicator of the oxygen cost of walking (Kaneko, Morimoto, Kimurma, Fuchimoto & Fuchimoto, 1990; Martin & Morgan, 1991; Zarrugy & Radcliffe, 1978).

In an early prediction equation by Bobbert (1960), body weight, gradient and speed of walking were employed as prediction variables. Although a sample size of only two subjects raises quastions of the validity and reliability of the formula, application to previous experimental data by regression analysis revealed a close agreement between the mean data measured and values predicted by the formula (Bobbert, 1960). Givoni and Goldman (1971), also utilized height, speed of walking and grade as predictor variables. There was a correlation between predicted and measured oxygen cost of 0.95 and the authors concluded that their equation may also be used to estimate the inherent biophysical processes determining the metabolic cost of other tasks.

Van Der Walt and Wyndham (1973) conducted a study to examine the oxygen cost of walking over a wide range of speeds and body weights in an attempt to develop a simple statistical model describing the oxygen cost of walking as a function of these two predictor variables. The study showed that oxygen consumption at a given velocity of walking was directly proportional to body mass, with a resultant correlation of 0.97. Similarly, Fellingham, Roundy, Fisher and Bryce (1978) found weight and speed squared, times body weight, to be the independent variables in a highly correlated regression equation ($r^2=0.86$).

Twenty years of published work on the oxygen cost of walking was reviewed by Workman and Armstrong (1986), who subsequently proposed a three compartment model to express the oxygen cost of walking. Compartment one constitutes approximately one third of the total oxygen cost and is analogous to the the body's basal metabolic rate. The second compartment consists of other elements affecting the oxygen cost of walking, specifically balance and posture. The final compartment is exponentially related to ground speed and is termed the metabolic cost of the walking movement. Workman and Armstrong (1986) established that short people use more oxygen than do taller people of the same body weight, at all speeds of walking, thus height has a small but consistent effect in the prediction of oxygen uptake in walking.

The concept of a total work model depicting the oxygen cost of walking was further examined by Ross and Jackson (1986), who developed the following formula:

$TW = A + (B \bullet \%G)$

where,

TW = total work performed to walk a given distance
A = horizontal work constant for the distance
B = vertical work constant for the distance
%G = percent grade

This model was found to be simple to use and the oxygen cost of walking was accurately estimated. When cross-validated with large samples of men of various ages over normal speeds, it was established that the model better predicted the oxygen cost of walking than other commonly used models (Ross & Jackson, 1986).

The prediction equation published by the American College of Sports Medicine (1988) is likely the most widely used equation at this time and is as follows:

$VO_2(ml \bullet kg^{-1} \bullet min^{-1}) = 0.1\ [velocity\ (m \bullet min^{-1})] + 3.5$

Recently the accuracy of the VO_2 values derived from this equation have come under scrutiny. Utilizing a modified Bruce protocol in patients with known coronary artery disease Smith, Borysyk, Dressendorfer Gordon and Timmis (1984) demonstrated that the observed VO_2 was 17% to 37% below that predicted by the ACSM equation. They cautioned that these results are confounded by the fact that steady state conditions may not have been met by the modified Bruce protocol and that the ACSM equation is premised on steady-state conditions. Overestimation of the oxygen cost of walking by the ACSM equation has also been found by Ross and Jackson (1986). A discrepancy between actual and predicted VO_2 of 14.9% was disclosed when male subjects averaging 45 years of age were tested on a standard Bruce protocol. Similar findings were disclosed by Ebbeling, Ward and Rippe (1988), who found the equation to overestimate the oxygen cost of walking at velocities between 1.5 and 3.5 mph in males and females averaging 28 years of age.

In male subjects between the ages 10-59 years the ACSM equation predicted the oxygen requirement of walking remarkably well at a constant velocity of 3 mph (Montoye, Ayen, Nagle, &

Howley, 1985). The authors concluded that further verification at other velocities was imperative. Similarly, Montoye et al. (1985) found the equation accurately predicted VO_2 during grade walking (6-18%) in adult males between 18 and 49 years. In the 50-54 and 55-59 year age groups Montoye et al. (1985) found the ACSM equation underestimated the oxygen cost of walking at 3 mph by 3-4 $ml \bullet kg^{-1} \bullet min^{-1}$. The same study reported the ACSM equation to underestimate the oxygen requirement of walking by approximately 0.5 $ml \bullet kg^{-1} \bullet min^{-1}$ in males under age 18 years. This notion was further substantiated in unpublished data by Wilkie, O'Hanky, Ward, Kline and Hosmer (1987), who found the ACSM equation significantly underestimated the oxygen cost of walking at all speeds, other than between 5.6 and 6.4 km/hr.

It is evident from the literature that further analysis must be conducted utilizing larger sample sizes, with broader age ranges and a variety of walking velocities. According to Workman and Armstrong (1963), good muscular coordination and training are necessary to walk efficiently. It then follows that untrained subjects, and special populations who walk poorly may not fit the equations that predict the oxygen requirement of horizontal treadmill walking and are thus worthy of special consideration.

In an early study by Bobbert (1960), the relationship between oxygen uptake and the speed of walking was investigated. These data were best described by a curvilinear relationship, thus suggesting a logarithmic relationship. From these results it was ascertained that the oxygen cost of walking increased with the square of walking velocity and that walking velocity was the major determining factor. This relationship was consistent with the findings of Blessey, Hislop, Waters and Antonelli (1976) and Cotes and Meade (1960), who also established a linear relationship between the square of the velocity of walking and the oxygen cost. Utilizing a suit calorimeter in a respiration chamber, Webb, Saris, Schoffelen, Van Ingen Schenau and Hoor (1988), established that the power output for external work increases with increasing speed of walking. Further to this, Webb et al. (1988) asserted that external power output is mainly dependant on walking speed and not other forces which influence the intensity of exercise.

Several studies have yielded conflicting results when examining the between sex difference in the oxygen cost of walking. At a walking velocity of 5.47 km/hr Booyens and Keatinge (1957) discovered that women expended significantly less oxygen than men per unit of body weight, taking significantly more strides and also significantly shorter strides than men. The between sex difference was found to be even more apparent at a walking velocity of 6.44 km/hr, with Booyens et al. (1957) suggesting that the women's lower oxygen uptake values were due to less work being performed to lift the body vertically. Further to this, a higher gross oxygen cost of walking in males was attributed to a 13% higher resting oxygen cost in a study conducted by Gehlsen and Dill (1977). When sex differences in the oxygen cost of standing were taken into consideration, any between sex differences were subsequently negated. Expressing the oxygen requirement of walking per unit body weight also revealed no significant between sex differences (Falls & Humphrey, 1976). Similarly, no between sex differences in oxygen uptake were found during walking at self-selected velocities (Bhambhami & Singh, 1985), normal, slow and fast velocities (Waters Lunsford, Perry & Byrd, 1988), or at the velocity eliciting the optimal oxygen consumption (Blessey et al., 1976; Zarrugh Todd & Ralston, 1974).

A dearth of information is available examining age-related effects on prediction of oxygen uptake during walking. From the available literature on age-related functional changes and gait parameters in the elderly, it is postulated these age-associated changes act synergistically on the oxygen transport system and thereby affecting oxygen uptake kinetics. The general consensus is that the aerobic demand of walking is adversely affected by advancing age in adults (Grimby & Soderholm, 1962; Pearce et al., 1983; Martin and Morgan, 1991). The prediction equations presently utilized would consequently be rendered invalid due to the lack of age-related compensations. Further discussion of age-related functional changes and alterations in gait parameters of the elderly will follow in subsequent sections of the literature review.

Age-related Functional Changes

"It is an axiom that life and the aging process start simultaneously (Astrand, 1988)". Aging is associated with growth up to, and including, most of the teen years and is thus considered a positive physiological force. Beyond the childhood years there is an almost linear increase in the probability of death with age (Shephard, 1988a). As active tissues, such as muscle, age they experience a decrease in enzyme activity, a loss of the capacity to replicate, impaired capability for protein synthesis and chemical regulation, and an overall decline in neuromuscular function (Kaneko et al., 1991; Shephard, 1988a; McArdle, Katch & Katch, 1986). Age-related morphologic and physiologic changes in the cardiovascular and musculoskeletal systems are well documented and are invariably evidenced by the altered functioning of these systems.

The integrity of the cardiovascular system imposes major limitations on the overall capacity to perform physical work or functional capacity in the aged. Functional aerobic capacity defines the limit of the circulatory system to adequately supply essential oxygen during times of increased aerobic glycolysis, as is the case during strenuous exercise. Maximal oxygen uptake is the best indicator of cardiorespiratory fitness and as such, is the single best measure of the integrity of the cardiovascular system. Cardiorespiratory fitness is an essential element in the maintenance of functional capacity with advancing age (Goertzen, Serfass, Sopko & Leon, 1984). In the elderly, the inability of organs, tissues and cells of the body to adapt to increased metabolic demands during strenuous exercise results in a decrement in physical work capacity or aerobic power (Emes, 1977).

It is a widely accepted fact that maximal aerobic power and the capacity for vigorous physical activity decline steadily with age (Cunningham, Rechnitzer, Pearce & Donner, 1982; Bruce, 1984; Kasch, Wallace, Van Camp & Verity, 1988). According to Bruce (1984) a decline in VO_2 max of -0.94 $ml \bullet kg^{-1} \bullet min^{-1}$ per year is normal in healthy men. When cross-sectional designs were utilized approximately one half this rate of decline in maximal oxygen uptake was disclosed (Bruce, 1984). It was, however, felt that only longitudinal approaches provided a reliable description of the effects of aging and consequently utilizing cross-sectional designs was cautioned against by Bruce (1984). Examining subjects over a 40 year interval, from age 30 to 70, Landin, Linnemeier, Rothbaum, Chappelear and Noble (1985) disclosed a reduction in overall work capacity to the order of 30%. In a summary of longitudinal data on age-related declines in maximal aerobic power, Kasch et al. (1988), concluded that a decline in maximal aerobic power of 1% to 2% per year is suggested. Although somewhat lower than previously suggested values, Kasch et al. (1988) observed a 12% decline in maximal VO_2 when 15 men were serially followed for twenty years.

Normal ranges for indices of maximal oxygen consumption, heart rate, cardiac index and stroke volume were compared by Hossack and Bruce (1982), in men and women between the ages of 20-75 years . All variables of cardiovascular function demonstrated a progressive decline with advancing age, with maximal oxygen consumption disclosing the most rapid decline. Possible structural changes in the cardiovascular system that may account for the age-related decrement in functional capacity were reviewed by Landin et al. (1985) who reported an overall loss of compliance of the ventricular muscle mass, heart valves, as well as the systemic vasculature are associated with aging (Landin et al., 1985). Other functional manifestations of aging included a decreased sensitivity to catecholamine stimulation, decreased cardiac output and decreased maximal oxygen consumption (Landin et al., 1985). Further substantiating these findings were those of Lakatta, Mitchell, Pomerance and Rowe (1987), who also disclosed decreased ventricular compliance and vascular distensibility. This coupled with an increase in left ventricular hypertrophy was instrumental in any age-related decline in functional capacity. More recently, Van Camp and Boyer (1989), cite similar morphological and physiological decrements in the cardiovascular system which culminated in an overall decreased left ventricular systolic function and thus, decreased cardiac output in the elderly.

Changes in resting and maximal heart rates aid in understanding age-related attenuations in cardiac output and the subsequent effects on predicting oxygen uptake from submaximal parameters (Shephard, 1988b). The resting heart rate of an adult depends largely on the fitness of the individual. A more fit individual is likely to have a higher stroke volume and consequently, a lower resting heart rate. Since some loss of cardiovascular function is associated with the aging process, a concomitant reduction in stroke volume and a parallel increase in resting heart rate result (Shephard, 1988a). According to Bruce (1978), a restricted chronotrophic capacity/reserve evidenced by a reduced peak heart rate in men is best expressed by the following relationship:

$$\text{max HR (beats/min)} = 210 - 0.662\ (\text{age})$$

An approximation of the change in maximal rate with age across sexes is expressed by the following relationship:

$$\text{max HR (beats/min)} = 220 - \text{age (years)}$$

It is evident from the above equations that there is an age-related linear decline in maximal heart rate. It then follows that at any given work intensity the older person is working closer to his/her maximal heart rate. Since a linear relationship between heart rate and oxygen consumption is largely met, especially at moderate intensity work, at any given work intensity the older individual is working at a higher percentage his/her max VO_2 (McArdle et al. 1986).

An overall decrease in muscular bulk and consequently strength is perhaps one of the most pronounced signs of aging. In comparing the strength of 65 year olds versus 25 year olds, a decrement of 60% has been suggested (Emes, 1977). Tzankoff and Norris (1977), utilizing total excretion of creatinine to measure muscle mass, found a total reduction of muscle mass with age of approximately one third, over 50 years of age. Both isometric and dynamic strength parameters are susceptible to age-related declines, with dynamic strength displaying the greater loss (Larsson, 1982). An age-associated reduction in muscle mass of 50% in comparison with young adult muscle has been observed by Landin et al. (1985). According to Strauss (1984), skeletal muscle accounts for 45% of total body mass between the ages 21 to 30 and only 27% at age 70. Muscle wasting may begin as early as 25 years of age and according to Lexell, Taylor and Sjostrom (1988), approximately 10% of the muscle area is lost by age 50. An acceleration in the loss of muscle area occurs thereafter, culminating in an overall loss of muscle area of approximately half. Decrements in muscle mass in the order of 10-20% have been demonstrated even in elderly subjects whose total body mass was maintained (Lakatta et al., 1987). In 100 females over age 65 years, Pearson, Bassey, and Bendall (1985), observed significant decrements in both absolute and relative strengths. Several possible mechanisms for age-related decrements in strength and muscle mass have been reviewed. According to Larsson et al. (1982) changes in male sex hormone, thyroid, corticosteroids, and insulin are likely instrumental in loss of muscle functioning with aging. Similarly, major structural and functional changes at the neuromuscular junction ultimately leading to a reduction in synaptic contact and in hormonal influence, have been postulated by Landin et al. (1985).

Age-related changes in composition of the aging human body reflect genetic and environmental factors such as physical activity, nutrition and disease, as well as normal aging (Steen, 1988). After age 35, the average Western adult will gain 0.2 to 0.8 kg of fat each year until the fifth or sixth decade of life (Parizkova, 1974). With aging there is likely to be an increase in fat mass and a tendency to deposit fat more internally than subcutaneously. The aging process brings about a loss of compliance in the tissues surrounding joints such as tendons and ligaments which leads to loss of flexibility and a general appearance of stiffness (Landin et al., 1985). Compensatory postural changes occur as a result of further weakening of the structural framework (Kaneko et al., 1991; Gallagher, 1990; Emes, 1977). Bone is also subject to these degenerative processes and as such displays age-related decrements in structure and function (Emes, 1977). An imbalance between bone formation and resorption leads to altered posture with a resultant average loss of height of 1.5 inches from age 20 to ages 65-75 and 3 inches by ages 85-94 (Strauss, 1984).

It is now clear that bone loss starts at different sites of the skeleton and progresses at different rates throughout life. According to Schaadt and Bohr (1988), the decrease in bone mineral content in the lumbar spine is predominantly related to menopause, whereas bone mineral content of the femoral neck decreases linearly from young adulthood to old age, and the bone mineral content of the femoral shaft does not decrease significantly until old age. According to Mosekilde (1989), age in and of itself is a major determinant of the skeletal changes during adult life. Some studies demonstrate that the bone of both the peripheral and axial skeleton is stable in women up to menopause, whereas other studies depict a loss in bone mineral content of the spine and femur commencing in early adulthood (Mazzes and Barden, 1991). Studies examining rates of bone mineral loss generally show that the effects of menopause are exponential and considerable, with the majority of loss in the first 5 to 7 years after menopause. This is likely a function of an increase in the activation of resorption sites (Gallagher, 1990). In the central trabecular region of the vertebrae, rates of bone loss range from 2.0 to 10.0 percent per year in post menopausal women (Chow, 1988; Gallagher, 1990). A much slower rate of decline in bone mineral content is demonstrated in cortical bone. Prior to menopause a degeneration rate of approximately 0.5 percent per year is common, with the rate of bone mineral loss accelerating to approximately 3% after menopause (Chow, 1988). Because of the tremendous future impact of osteoporosis in the aged population a clear understanding of the pathogenesis of the disease should aid in the development of strategies aimed at prevention, the most fundamental of which being the adaptation of a more habitually active society.

Prevalent social attitudes that militate against regular physical activity in the elderly have disillusioned the elderly population into believing that even moderate exercise will precipitate injury, chronic exhaustion and even illness (Bassey, Fentem, MacDonald & Scriven, 1976). Consequently, an overall diminished expectation of the elderly in our society is evident. In short, the decree held by our society that older people should "slow down" and "take a well-earned rest" has altered the aged population's perception of exertion, fascilitating this self-fulfilling prophesy and entrenching the adoption of a more sedentary lifestyle as the norm in the elderly (Shepherd, 1989).

Participation in spontaneous physical activity drops off precipitously with increasing age (Bassey, 1978). The aging process is generally associated with a gradual reduction in activity and an acceptance of a more sedentary lifestyle (Emes, 1977). According to Goertzen et al. (1984), the average inactive 70 year old woman has a functional capacity of only approximately 4.5 METS, which would allow her to pursue activities like walking, golfing and pushing a light lawn mower for only a short period of time. This decrement in physical activity associated with aging may in fact not be the norm, according to the Canada Fitness Survey (1981), which suggested that surprisingly little age-associated decline existed in habitual activity adults. Some gerontologists distinguish the young-old (typically aged 65-74 years, and without restriction of physical activity), the middle-old (typically aged 75-84 years, with some limitation of their physical capacity) and the very-old (typically 85 years or more, with severe limitation of physical activity). However, it is well recognized that not all people age at the same rate. It is now evident that older people who remain habitually active and socially involved as long as possible are better able to cope with the stresses of everyday life and are more likely to reduce morbidity and possibly mortality from chronic disease, especially cardiovascular disease (Bruce, 1984; Wilson, 1981; Emes, 1977)

Difficulty discriminating between the effects of true aging and those due to a sedentary lifestyle can potentially confound research on age-related effects. In a study comparing active and sedentary men aged 40 to 74 years, Dehn and Bruce (1972), found a significantly greater decrease in VO_2 max among those who were not habitually active. Comparing habitually active adults versus their sedentary cohorts, Bruce (1978) demonstrated a two-fold difference in the rate of decline in maximum VO_2 in middle-aged men. Similarly, when comparing healthy sedentary and active men aged 50 to 72 years Heath, Hagberg, Ehansi and Holloszy (1981) found an almost two-fold greater decrement in functional capacity in the sedentary men. A 50% to 75% discrepancy in cardiac output at peak exercise among individuals with different activity patterns has been observed by Lakatta et al. (1987). They conclude that these changes in cardiovascular function attributed to aging may be due in part to a sedentary lifestyle. In a summary paper by Shephard (1989), inactivity was felt to lead to a rapid loss of physical condition, with an associated deterioration in mental function. Van Camp and Boyer (1989) surmised that the observed decline in exercise capacity may be exacerbated by musculoskeletal difficulties, family or physician concerns, depression, or personal concerns. It then follows that a combination of an age-related decline in habitual activity and alterations in physiologic function and musculoskeletal structure are likely mechanisms for any decrement in functional capacity (Kaneko et al., 1991; Thomas, Cunningham, Rechnitzer, Donner & Howard, 1985).

There is strong evidence that the decline in functional capacity is neither inevitable nor, once it has developed, permanent (Van Camp & Boyer, 1989). Perhaps the most convincing data supporting the notion comes from the College Alumni Study, in which more than 1600 men who entered college between 1916 and 1950 have been tracked (Paffenbarger, Wing & Hyde, 1978). These results unequivocally illustrate a reduction in myocardial infarction and sudden death in those participating in regular physical activity, when compared to their sedentary counterparts. Although Kasch et al. (1988) suggest that age does slowly affect cardiovascular function, the effect is much less than previously asserted. The authors conclude that physical activity is capable of forestalling the deleterious effects of aging.

Other benefits incurred through a program of regular physical activity include: a reduction in anxiety and tension (Steinhaus et al., 1990; Pocari, Ward, Morgan, Mance & Ekkelbery, 1988); reduced serum cholesterol (Cook et al., 1986); increases in bone mineral content (Dalsky, Slocke, Ehsani & Slatopolsky, 1988) and favorable changes in body mass and body fat (Lakatta et al., 1987; White, Yeater, Martin, Rosenberg & Sherwood, 1984; Pollock, Miller, Janeway, Linnerud, Robertson & Valentino, 1971).

The concern for protecting middle-aged and older subjects from overstress is important, and much caution must be used in prescribing programs for this population. To that end, older sedentary people need more time to adapt to a training program (Pollock, Wilmore & Fox, 1984). Long term, low-intensity, "lifestyle activities" such as walking, would then appear to be a viable alternative for training the older adult (Jette, Sidney & Campbell, 1988).

By comparing the aerobic benefits of walking with other forms of training at comparable intensities, Pollock, Demmick, Miller, Kendrick and Linnerud (1975) established that walking had comparable aerobic benefits. The effects of a 12 week walking program on maximal and submaximal work output indices in middle-aged men and women were examined by Jette et al. (1988). A reduction in submaximal heart rate averaging 13.7 beats per minute was found to be consistent with previous studies by Cunningham and Hill (1975) and Pollock et al. (1971). According to Pocari, McCarron, Freedson, Ward and Ross (1987), fast walking was an adequate stimulus for cardiovascular endurance in men and women between the ages of 30 and 69 years. Target heart rate (70% of heart rate maximum, THR) was attained in 66.7% of men and 91% of women, with walking pace best predicting the attainment of THR.

The possibility of a sex difference in activity pattern of the aged has been addressed by several authors, yielding conflicting results. During the week, women were shown to be habitually more active that men, however the men were considerably more active on the weekend (Sidney and Shephard, 1977). According to McPherson

(1982), any age-related decline in habitual activity is more pronounced in women than in men. Shephard and Montelpare (1988) determined through questionnaire that men (but not women) reduce their level of physical activity as they pass through the retirement years. Their explanation for this lies in the fact that at age 50 men are considerably more active than their female counterparts, whom have already assumed a more sedentary lifestyle.

Comparison of Overground and Treadmill Walking

The use of a motor-driven treadmill is commonplace in studies of locomotion and for training and rehabilitation purposes (Williams, Hone & Carter, 1992). There is common agreement that for research purposes the utilization of a motor driven treadmill enables better reproducibility. The use of a treadmill provides a means for measurements to be conveniently taken without disrupting the subject, or following him/her around with equipment (Wall & Charteris, 1980). Although there may in fact be differences between the oxygen cost of walking or running on the treadmill and overground, in many situations the convenience of the treadmill outweighs any differences encountered (Wall & Charteris, 1981). The inherent ability to replicate external conditions on a treadmill maximizes internal validity (Arsenault, 1986). However, before results from treadmill tests can be generalized to the outdoor setting, the question of whether there are differences between the oxygen cost of walking on the treadmill and overground (external validity) should be resolved.

The likelihood of kinematic differences between treadmill and overground walking has been addressed in several studies. According to Daniels, Vanderbie and Winsmann (1953), a change in body mechanics occurs during treadmill walking. Examining locomotion on the treadmill, they assert that utilizing a motor-driven belt may contribute a portion of the energy necessary to elevate the body during walking. However, this finding was not substantiated by Ralston (1960), who concluded that the contribution of the motor was insignificant and more attention should be paid to walking surface. Other explanations for the heterogeneity between treadmill and overground locomotion are variances in visual and, to a lesser degree, auditory information (Van Ingen Schenau, 1980). In that regard, the lack of movement of the surroundings during treadmill walking may induce kinematic differences in locomotion and/or oxygen consumption. In boys between the ages of 9-16 years walking at identical speeds, Van Ingen Schenau (1980) demonstrated significantly shorter mean stride lengths when comparing treadmill to floor walking, thus indicating kinematic differences associated with treadmill walking.

Possible difference in kinematics and/or oxygen cost on the two surfaces have been divided into three categories: (1) proprioceptive and/or exteroceptive feedback, (2) air resistance, and (3) sensory feedback (Pearce et al., 1983). Proprioceptive and/or exteroceptive feedback could be altered if a non-uniform belt velocity were utilized. Similarly, Bassett et al. (1985), agree that perceptual difficulties with treadmill locomotion, as well as variation in belt speed with each footplant may account for observed differences in kinematics between treadmill and floor walking.

The issue of whether kinematic differences between treadmill and overground walking are reflected in the oxygen cost of the activities has been investigated by several authors with confounding results. Oxygen requirements approximately 10% lower on the treadmill than on an asphalt road or cinder path have been reported by Daniels et al. (1953). Their subjects were wearing leather combat boots and according to Givoni (1971), the additional load on the feet of approximately 1 kg. should be adjusted for. According to Williams et al. (1992), a difference in oxygen cost will result whenever dissimilar surfaces with distinct kinetic characteristics interact with biomechanical movement. Utilizing three different walking speeds (normal, fast and as fast as possible), Pearce et al. (1983) established that lower oxygen uptake values were associated with treadmill in comparison with floor walking. A significant interaction of age with both floor and treadmill speed was also evident.

In disagreement with these findings are those of Ralston (1960), who concluded that no significant difference existed between the oxygen cost of treadmill walking and floor walking. In coronary patients, Jankowski et al. (1972), found no differences between the oxygen cost of gymnasium and treadmill walking at speeds between 2.5 and 4.5 miles per hour. According to Arsenault (1986), no differences existed between the Electromyographic activity of locomotion on a walkway and treadmill, further substantiating the external validity of treadmill walking.

In two kinematic studies examining the process of habituation in treadmill walking, gait parameters have been shown to be more variable on the treadmill than overground walking (Wall and Charteris, 1980; Wall and Charteris, 1981). Upon examination of habituation during treadmill walking, the initial accommodation to the new modality is characterized by a tripping/balance regaining gait followed by a gradual lengthening of stride and general acclimatization as confidence increases. Subjects were found to be still habituating after 10 minutes on the treadmill, displaying greater variability in gait parameters from stride to stride, than in overground walking (Wall and Charteris, 1981). In conclusion, they suggest that subjects should be previously habituated in distributed practice sessions for about 1 hour, and then not measured within the first 2 minutes of performance.

The repeatability and consequently, the reliability of testing is essential when studying the oxygen cost of specific activities. The repeatability of oxygen uptake measurements on the treadmill at all combinations of speed and grade has been observed by Erickson, Simonson, Taylor, Alexander and Keys (1945). The replicate variability of the measurement was found to be 2.95% of the grand mean and independent of speed and grade up to 4.0 m.p.h. and 10% grade (Erickson et al., 1943). Test-retest reliability has also been examined by Kirby and Marlow (1987), who asserted that a single test can accurately predict the results of subsequent tests. Further to this, they state that treadmill tests can be truncated without much loss in predictive ability and the testing interval may be as long as four weeks or as short as fifteen minutes, without much loss in reliability.

Patterns of Gait in the Elderly

A normal pattern of gait requires a highly coordinated integration of the nervous, muscular, skeletal, circulatory and respiratory systems (Imms & Edholm, 1981). It then follows that any disruption in the integration of these systems would likely be manifested as an increase in the variability of gait parameters. In an attempt to quantify pathologic patterns of gait, eight components of "normal" gait have been identified by Hough, McHenry & Kammer (1987). Gait must be initiated smoothly, with step length and height remaining consistent, thus maintaining a smooth pattern of walking. The path of gait should be in a straight line with little or no side-to-side motion and the heels should almost touch as they pass each other. Hough et al. (1987) concluded that turning should be smooth, and a heel/toe action should be utilized throughout normal gait.

Age-related declines in mobility are commonplace in our society. When examining age-related changes in mobility it is important to differentiate between those directly associated with aging and those manifested due to disease states. In healthy individuals, no difference in gait parameters have been attributed solely to the aging process. In an early study by Finley, Cody and Finizie (1969), age per se, did not affect gait characteristics in women between the ages of 64 to 86. Similarly, no difference in the variability of gait parameters across age groups was found by Gabell and Nayak, (1984). Any increase in the variability of gait in "normal" young and old adults was attributed not to aging, but to pathology and any increase in the variability of gait should not be regarded as normal aging (Gabell & Nayak, 1984). In agreement with these findings are Rikili and Busch (1986) and Imms et al. (1981), who determined that walking performance was more associated with pathology and level of habitual activity, than aging.

Older men typically give the impression of a guarded or restrained type of walking in an attempt to obtain maximum stability and security (Murray, Kory & Clarkson, 1969). Evidence of a prehensile walking pattern has also been observed in older women who demonstrated characteristically different gait patterns from their younger cohorts (Murray Kory & Sepic, 1970). Several gait components in men aged 60 to 65 years differed from the younger men, which suggests a less efficient walking pattern in the older men. Older men characteristically showed alterations in stride length and frequency and ultimately in the speed of walking (Murray et al., 1969). This general suppression of the pattern has been described as "normal" by Finley et al. (1969). Shorter steps and longer periods spent in the support phase constrains the bodies centre of mass, rendering a more secure pattern of gait, according to Finley et al, (1969). The effort required to maintain stability during walking in the elderly was very real and perceptible. By increasing the double support time and lowering step rate the individual was rendered more secure (Kaneko et al. 1991). Gabell et al. (1984) also assert that controlling spatial (stride width) and temporal (double-support time) components resulted in an enhanced control of balance. In a study by Cunningham et al., (1986), the freely chosen speed of walking although correlated with age (up to 66 years) appeared to be more strongly related to level of habitual physical activity. According to Waters et al. (1988), the relative gait velocity was lower in the older subjects than for the younger adults. This was believed to be concurrent with the decrease in the other physiological parameters of maximal performance, such as maximum aerobic capacity and maximal muscle strength, which normally decline in older subjects (Waters et al., 1988). An age-related decline in chosen walking speed of 7% was found by Bendall, Bassey and Pearson, (1989). Associations between velocity of walking and other factors may lead to further understanding of possible mechanisms of restoring walking speed in the elderly, according to Bendall et al. (1989). Similarly, Winter, Patla, Frank and Walt (1990), suggest that an increase in double-support time, shorter step length and a reduced push-off, may explain any changes observed in gait of the aged.

Little data are available on the deleterious effects of aging on sensory input and subsequently, postural control while walking. During ambulation, loss of equilibrium and concomitant sensory compensation occurred with each stride (Larsson, Odenrick, Sandlund, Weitz & Oberg, 1980). Postural instability, often called postural sway, increased with age, particularly in women (Wolfson, Whipple, Amerman, Kaplan & Kleinberg, 1985). One essential element in controlling postural sway was visual acuity (Wolfson et al., 1985). In the elderly population, decreased visual acuity, restriction of the visual field, increased susceptibility to glare and poorer depth perception, have all been demonstrated (Stelmach & Worringham, 1985). In agreement are Wolfson et al. (1985), who were able to demonstrated that a decline in visual input resulted in increased postural instability and subsequently postural sway.

Several studies have substantiated an age-related change the oxygen cost for similar workloads. Durnin and Mikulicio (1956) and Grimby and Sodderholm (1962) reported significantly higher VO_2 in treadmill walking in older subjects. The oxygen consumption data was reported in gross and not relative terms and since the older subjects were, on average heavier, the results are questionable. Fisher and Gullickson (1978) described six basic musculoskeletal determinants of normal gait. Pelvic rotation, pelvic tilt and knee flexion all act to flatten the arc through which the centre of mass translates. Foot and knee mechanisms, as well as lateral hip displacement, help smooth gait and form the typical sinusoidal pattern, thus minimizing the oxygen cost. Fisher and Gullickson (1978) emphasized that an increase in the oxygen cost of ambulation occurs when one or more of these musculoskeletal determinants are abnormal. Since aging has been proven to have deleterious effects on the musculoskeletal system, it then follows that the determinants outlined by Fisher and Gullickson (1978) may be adversely affected by the aging process. In the longitudinal data of Montoye (1982), exercise oxygen consumption was reported to be only slightly higher in older persons, when compared to their younger counterparts. However, an increased respiratory exchange ratio suggests that anaerobic glycolysis was involved, which is indicative of an overall decline in efficiency of older individuals. Similarly, Bassey and Terry (1986) found that the oxygen cost of walking in elderly females was significantly greater than that of their younger cohorts. With reciprocal changes in the physical work capacity and oxygen uptake kinetics affecting maximal parameters, it would then follow that low to moderate intensity exercise and similar methods of testing, such as submaximal testing, would be most applicable in the aged population.

Submaximal Exercise Testing in Elderly Populations

Standardized submaximal testing to assess the volume of oxygen consumed during a given activity has many advantages, particularly in a aging population (Leblanc, Bouchard, Godbout and Mondor, 1981). Numerous methodological differences in the equipment utilized, the time course of measurements and the mode of work itself, make standardization an important tool if the testing results are to be valid and repeatable, and thus generalizable to a broad population range. It is generally recognized that submaximal testing is repeatable, and when standardized protocols are utilized, most of the intra-individual variability is understood to be biological variation rather than experimental measurement error (Sime, Whipple, Berskson, MacIntyre & Stamler, 1972; Leblanc et al., 1981). Issues important to the standardized administration of submaximal tests include a combination of environmental and physiologic parameters at the time of the testing such as the temperature, prior meals, previous activity, time of day and emotion.

Submaximal tests have been found to be a valid and reliable means of assessing cardio-respiratory function. Since pulse rate at submaximal levels is systematically related to higher levels, it then follows that the use of a carefully standardized test of submaximal exercise capacity in homogeneous populations can assess a subject's heart rate response to exercise and derive an index of performance (Taylor, Wang, Rowell, Blomqvist, 1963; Kline et al., 1987). The concept of a self-paced walking test specific for the elderly was first established by Bassey et al. (1976). The test was found to be relevant to the demands of daily living and a realistic method of assessing longitudinal age-related changes arising possibly from changes in habitual activity, illness, diet, or aging itself (Bassey et al., 1976). Subsequent investigations by Cunningham et al. (1982) and Cunningham et al. (1986) have verified that tests of self-paced walking are viable indicators of a subject's hemodynamic response to exercise and the capacity to perform physical work.

Relatively few studies have reported the effects of age on metabolic responses to submaximal exercise. A slower response to exercise irrespective of present activity levels, was demonstrated by Wessel, Small, Van Huss, Huesner and Cederqiust (1966). In agreement with this were Cotes, Hall, Johnson, Jones and Knibbs (1973), who emphasize that age should be taken into account when interpreting cardiac frequency during submaximal exercise. Also in accordance with these findings were those of Montoye (1982), who suggested that although oxygen uptake at submaximal work loads is not much different in older adults, the increased respiratory exchange ratio (RER) was indicative of a greater contribution of the anaerobic pathways. Similarly, an age-related difference in RER was demonstrated by Gardner, Poelman, Sedlock, Corrigan and Siconolfi (1988), who employed male subjects with an average age of 42.3 years. Although the men expended an equivalent amount of oxygen to perform the exercise sessions, an age-related difference in the RER was indicative of differences in the relative contribution of aerobic and anaerobic pathways.

Chapter 3

METHODS AND PROCEDURES

Subjects

Ten adult women, 59 years of age and older, with variable levels of physical activity were recruited for this study. All were non-smokers who consumed less than five ounces of alcohol per week and were considered clinically healthy (i.e. free from cardiovascular, pulmonary or metabolic diseases that would preclude safe participation in an exercise program).

Prior to inclusion in the study, the subjects completed a medical history questionnaire and informed consent which described the experimental protocols, as well as any associated risks or discomforts. Copies of these forms are included in the appendicies. All testing procedures were approved by the Faculty's human ethics committee.

All the subjects were recruited from the Kinsmen Reh-Fit Centre, a non-profit organization dedicated to the care and prevention of cardiovascular disease through exercise, education and encouragement. The group initially consisted of 12 subjects, however one subject was unable to complete the testing protocols and another one was excluded due to measurement errors discovered during the data analysis. The minute ventilation was found to be exceedingly high in this subject, due most certainly to hyperventilation.

Screening

All subjects gathered at the Reh-Fit Centre where the experimental objectives and procedures were described. Following this a Physical Activity Readiness Questionnaire (PAR-Q, British Columbia Ministry of Health, 1978; Appendix 4.), medical history questionnaire and an informed consent were completed and signed (Appendix 5.). All were instructed that even after signing the above forms, they were not committed, and were free to withdraw for the experiment at any time.

Following this, the subjects were assembled in pairs at the Max Bell Centre, at the University of Manitoba. An introduction to the gas analysis equipment was conducted at this time and subjects were fitted for the headgear and mouthpiece. They were then connected to the gas collection apparatus and did a 5 minute walk on the track and the treadmill at a freely chosen pace to familiarize them with the equipment and methods being used in the study. Provided there were no obvious apprehensions on the subject's behalf which may have interfered with the testing procedures, the subjects were accepted into the study at this point.

Experimental Design

A test/retest design was used in this study. The subjects performed two successive track tests followed by two successive tests on the treadmill. All tests for each individual were conducted at the same time of the day (within one hour) and the maximum time span between an individual's four tests was one month. Both the track tests were completed first and treadmill velocity was matched to the velocity of the second track test.

Procedures

Track Test

Standardized instructions were administered verbally for each testing session. Resting heart rate was acquired after a five minute period of seated relaxation, utilizing a portable electronic monitor (Sport Tester, Polar Electro). Each subject's target heart rate corresponded to 50% heart rate reserve according to the methods of Karvonen (1957):

$$\text{HRR} = \text{HRmax} - \text{HRrest}$$

$$\text{HRmax} = 220 - \text{age}$$

$$50\%\ \text{HRR} = ((\text{HRmax} - \text{HRrest}) \bullet 0.50) + \text{HRrest}$$

where:

HRR = heart rate reserve

THR = target heart rate

HRmax = heart rate maximum

50% = target heart rate testing intensity

The track tests were conducted on an indoor, oval track (200m) at the Max Bell Centre, University of Manitoba. During a preliminary warm-up which consisted of five minutes walking on the testing apparatus, heart rate was gradually increased until the target heart rate range was achieved (50% HRR ± 2.5 bpm). A ten minute steady state walk was then performed with the electronic monitor programmed to alarm if the subject deviated from the desired range. Expired gases were collected during the final two minutes of the steady state walk by means of Douglas bags suspended from a mobile collection apparatus constructed specifically for this study and modeled after the apparatus of Daniels (1971). Gas analysis was conducted within ten minutes after completion of the test with volume and concentration determination as described in the following sections. Upon completion of the test the subject was then disconnected from the gas analysis equipment and warmed down to the point of comfort.

Treadmill Test

The velocity for the treadmill test was set to the velocity of the second track test ± 0.10 mph. Subjects walked on a level treadmill (0% grade) for a five minute warm-up period, during which time the treadmill speed was gradually increased to the desired speed. With the speed held constant, the subjects then walked at steady state for ten minutes. Expired gases were collected and analyzed employing the identical methodology and equipment described in the track test. Heart rates were monitored using a portable heart rate monitor (Polar Electro).

Determination of Gas Volume and Concentration

Expired gases were collected with the aid of a modified Douglas Bag system. Mixing of the gas was done manually for one minute prior to analysis. A sample of gas (approximately 125 ml.) was bled off and siphoned into the breath by breath port on the Metabolic Measurement Cart (Sensormedics) and fractional concentrations of oxygen and carbon dioxide were determined. Volume was measured using a vacuum pump to draw the gas through a dry gas meter (Parkinson Cowan).

Calculation of Oxygen Uptake

Oxygen and carbon dioxide values were automatically calculated by the Metabolic Measurement Cart (Sensormedics) and printed up at five second intervals, for fifteen seconds. Calibration of the Metabolic Measurement Cart for accuracy and linearity was done immediately before and after each measurement, using gases of known concentration. Volume verification was read off the display dials of a Parkinson Cowan dry gas meter which was calibrated using a tissot spirometer. All measurements were performed at the University of Manitoba Sport and Exercise Sciences Institute. Oxygen uptake was calculated according to the methods of the American College of Sports Medicine (1988, Appendix 1.).

Anthropometric and Body Composition Measurements

All anthropometric measurements were conducted at the University of Manitoba, Sports and Exercise Sciences Institute. Body height was measured to the nearest 0.1 cm, with the subject standing flat footed against the wall, not wearing shoes. Body weight was measured in bathing attire, to the nearest 0.1 kg, using a digital scale (Digi, Japan). Skinfold measurements were taken at the biceps, triceps, subscapular, iliac crest, abdominal, frontal thigh and medial calf locations using Harpenden Calipers (H.E. Morse Co., England). A full set of skinfold measurements was done. Measurements were made to the nearest 0.2 millimeters. This was followed by a second set of measurements. If the difference between the paired measurements was more that 0.4 mm a third measurement was taken. The mean of the the two closest values was considered the true value. Body fat was estimated according to the methods of

Jackson et al. (1980). Girth measurements at the neck, arm, forearm, wrist, chest, waist, abdominal, gluteal, upper-thigh, mid-thigh, calf and ankle locations were taken using a metal tape (Lufkin Executive Thinline, USA). Measurements were taken to the nearest 0.1 cm and the mean of the two closest measurements was used as the true value. In the same manner, bone breadths at the appropriate anatomic sites were measured using aluminium calipers (Siber-Hegner, Switzerland). The formula of Martin, Spenst, Drinkwater & Clarys, 1990 (Appendix #2) was used to calculate muscle mass. All measurements were conducted by two researchers, one as measurer and the other the recorder. To maximize inter-tester reliability, all measurements were done by the same researcher throughout the course of the study. Fat free mass was calculated according to following relationship:

$$FFM = BW - (BW \times \%Fat)$$

where:

FFM= fat free mass
BW= body weight

Data Analysis

After completion of all testing measures, values from all printouts and worksheets were entered into a spreadsheet on an Apple Macintosh Plus. Mean values for all variables were then calculated for all the raw data. Predicted values for oxygen uptake were calculated using the ACSM equation. Mean values were then transferred to Statview for statistical analysis and finally to Cricket Graph for graphical presentation.

Mean steady state oxygen uptake was calculated for each trial of both walking protocols. Repeatability of track walking velocities was tested by between-trial comparison using a two-tailed Student's t-test at a probability of 0.05. The first hypothesis, or the repeatability of both protocols, was tested using a t-test to assess any between-trial difference in measured oxygen uptake. The presence of any possible learning or apprehension effect was assessed by conducting a t-test between the oxygen upatake during second track and the second treadmill tests. The second hypothesis, or the generalizability of treadmill measures of oxygen uptake to like measures on the track, was tested by a between-protocol comparison of measured oxygen uptake values using a t-test. Predicted oxygen uptake values were generated using the walking velocity of the second track test using the ACSM prediction equation (ACSM, 1988). The third hypothesis, or the efficacy of the ACSM prediction equation, was tested by t-test comparing predicted oxygen uptake values (predictor) to measured values on both protocols (criterion). Regression analysis was used to evaluate the meaningfulness of the prediction equation in regard to measured oxygen uptake.

All variables were regressed against oxygen uptake on the track to determine the single best predictor of oxygen uptake. Stepwise regression was used to determine the two variable combination that best predicted the oxygen uptake on the track. All variables were also regressed against age to determine any potential age-related trends.

Chapter 4

RESULTS

Introduction

The first objective of this investigation was to determine the repeatability of a low intensity steady state walking test on the track and treadmill in an elderly population. Additionally, the generalizability of oxygen uptake measures on the treadmill to measures overground at the same velocity was assessed. Finally, the ability of oxygen uptake values predicted from the ACSM equation to accurately reflect measured oxygen uptake during like measures on the track and treadmill was assessed.

1.0 Physical Characteristics of the Subjects

Ten women between the ages of 59 and 73 years were studied. The physical characteristics of the subjects with group means, standard deviations and ranges are shown in Table 4.1. Common variables for body fat assessment and anthropometric measures are represented in Table 4.2 and 4.3, respectively. By comparison with data from the Canada Fitness Survey (1981), the following mean percentile ranks were disclosed for: height (65%), mass (50%), body mass index (BMI, 65%), sum of triceps, biceps, subscapular, iliac crest and medial calf skinfolds (SOS, 60%), waist to hip ratio (WHR, 55%) and sum of subscapular and iliac crest skinfolds (SOTS, 50%). This represented a mean study group percentile rank of 57.5.

Table 4.1. Physical characteristics of the subjects (n=10)

Variable	Mean	S.D.	Range
Age (yrs)	65.4	4.5	59.0-73.0
Height (cm)	160.0	5.8	149.9-167.8
Mass (kg)	61.6	9.0	48.7-71.5
BMI(kg/cm2)	24.0	2.6	20.7-27.9
WHR	0.80	0.05	0.7-0.0
BF (%)	27.3	4.7	20.3-34.7
FFM (kg)	44.5	5.3	36.6-50.3
MM	22.8	4.1	15.2-28.6
%MM	37.3	5.9	23.6-43.5

KEY: S.D. (standard deviation), BMI (body mass index), WHR (waist to hip ratio), BF (body fat), FFM (fat free mass), MM (muscle mass).

Table 4.2. Skinfold measurements of the subjects (n=10)

	Mean	S.D.	Range
Tricep (mm)	18.2	3.7	12.5-23.1
Abdominal (mm)	27.2	8.6	17.7-43.2
Iliac Crest (mm)	18.2	6.6	9.3-30.6
Thigh (mm)	34.1	21.9	6.7-88.8
SOS (mm)	75.4	21.0	50.0-106.3
SOTS (mm)	34.0	13.0	16.2-55.0

KEY: S.D. (standard deviation), SOS (sum of triceps, biceps, subscapular, iliac crest and medial calf skinfolds), SOTS (sum of subscapular and iliac crest skinfolds)

Table 4.3. Girth and breadth measurements of the subjects (n=10)

	Mean	S.D.	Range
Girths			
Arm (cm)	28.0	3.0	22.2-31.1
Forearm (cm)	22.7	3.1	14.5-25.8
Wrist (cm)	22.0	21.3	14.3-82.6
Chest (cm)	87.2	8.5	71.5-95.2
Waist (cm)	79.4	8.3	63.9-89.1
Abdominal (cm)	91.5	8.8	74.8-104.9
Upper Thigh (cm)	55.7	5.6	42.1-62.0
Gluteal (cm).	94.0	15.9	52.4-107.7
Mid Thigh (cm)	46.3	5.4	32.3-51.7
Calf (cm)	33.1	5.1	18.9-37.2
Neck (cm)	32.3	1.7	29.9-34.4
Bone breadths			
Humerus (cm)	6.6	0.5	6.0-7.3
Wrist (cm)	5.2	0.3	4.5-5.7
Ankle (cm)	6.72	0.4	6-7.2
Femur (cm)	9.3	0.4	8.6-10.0

KEY: S.D. (standard deviation)

2.0 Repeatability of Track and Treadmill Tests

Measurements of velocity, oxygen uptake and heart rate were taken on successive measures for both the track and treadmill tests. None of the subjects had difficulty habituating to either the treadmill walking, gas analysis apparatus or heart rate monitor. Table 4.4 shows velocity (mph.), VO_2 (measured in ml•kg^{-1}•min^{-1}) and heart rates (bpm.), for the track and treadmill tests, on two successive occasions. Normalizing heart rate at 50% heart rate reserve for both track tests precludes statistical comparison of heart rates. It does, however, enable comparison of walking velocity at this predetermined physiologic load. Repeat measures of walking velocity during the track test revealed no significant difference.

Because there was no difference in velocity between measures on the track, treadmill velocities were matched with the second track test velocity. Heart rates measured at identical velocities on successive treadmill tests were not significantly different from one another.

There was no significant difference in oxygen uptake measured for track walking on successive occasions, or for successive occasions on the treadmill (Table 4.4).

Table 4.4. Descriptive statistics for track and treadmill variables (n=10)

	Trial 1		Trial 2		
Variable	$\overline{X}$	S.D.	$\overline{X}$	S.D.	t
Track velocity	3.27	0.44	3.32	0.41	-1.17
Treadmill velocity	3.32	0.41	3.32	0.41	0.00
Measured track $V0_2$	17.41	4.08	18.96	4.15	-1.88
Measured treadmill $V0_2$	16.79	2.37	16.88	2.92	0.36
Track heart rate	115.00	5.89	115.00	5.89	0.00
Treadmill heart rate	110.40	7.68	111.60	9.50	-0.57

Key: All velocities are in miles per hour, oxygen uptake ($V0_2$) in $ml \bullet kg^{-1} \bullet min^{-1}$ and heart rates in beats per minute
Note: No values were significant at $p<0.05$

3.0 Generalizability of Treadmill Measures of Oxygen Uptake to Measures on the Track

As previously outlined, the ability of treadmill oxygen uptake measures to accurately reflect like overground measures is invaluable, particularly when large samples must be evaluated cost effectively. Since there were no significant differences in oxygen uptake between trials for either the track or treadmill tests, the data were pooled. Average oxygen uptake values on the track and treadmill were: $(17.41+18.96)/2=18.19 \pm 3.90$ $ml \bullet kg^{-1} \bullet min^{-1}$ and $(16.79+16.88)/2=16.84 \pm 2.55$ $ml \bullet kg^{-1} \bullet min^{-1}$, respectively. This represents a mean difference of 1.35 $ml \bullet kg^{-1} \bullet min^{-1}$, or approximately 8%. A t-test was used to determine whether the oxygen uptake on the track and treadmill was significantly different. Track walking at 3.32 mph elicited a higher oxygen uptake, though this difference was not significant (Table 4.6).

To determine whether oxygen uptake from the treadmill test could be used to accurately reflect oxygen uptake on the track, simple regression analysis was used. This revealed that 44% of the variability in track oxygen uptake can be attributed to the variability in oxygen uptake on the treadmill. The relationship between track and treadmill values is shown in Figure 4.1. The equation for predicting oxygen uptake on the track from oxygen uptake on the treadmill is as follows:

Pred. $VO_{2\,TR} = 1.01 \bullet VO_{2TM} + 1.173$, SEE = 3.11

Table 4.5. Regression summary table for track and treadmill measures of oxygen uptake

Variable	r^2	S.E.	p
Measured treadmill vs track	0.44	3.11	0.04
ACSM predicted vs treadmill	0.62	1.67	<0.01
ACSM predicted vs track	0.55	2.78	0.01

KEY: ACSM (American College of Sports Medicine).

Table 4.6. Comparison of actual treadmill, track and predicted $V0_2$ values

Variable	t	p
Average measured treadmill vs track	-1.44	0.18
Trial #2 measured treadmill vs track	-2.22	0.05
ACSM predicted vs treadmill	-7.75**	<0.01
ACSM predicted vs track	-5.82**	<0.01

KEY: ACSM (American College of Sports Medicine).
Note** significant at $p<0.01$

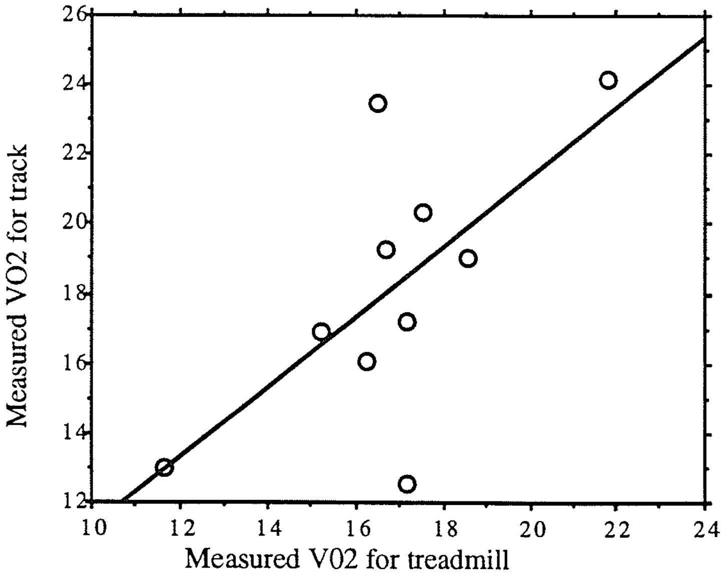

Figure 4.1- Linear regression of measured treadmill VO_2 versus track VO_2 (n=10)
Note: All VO_2 values are averages in ml•kg^{-1}•min^{-1}

4.0 Efficacy of the American College of Sports Medicine Prediction Equation

The predicted oxygen uptake at a velocity of 3.32 mph using the ACSM equation was 12.37 $ml \bullet kg^{-1} \bullet min^{-1}$. As can be seen from Figure 4.2, the ACSM prediction equation significantly underestimates ($p<0.01$) the oxygen requirement of walking both during treadmill (-4.5 $ml \bullet kg^{-1} \bullet min^{-1}$, or 26.5%) and track walking (-5.8 $ml \bullet kg^{-1} \bullet min^{-1}$, or 32.0%). This represents a mean underestimation of approximately 5.2 $ml \bullet kg^{-1} \bullet min^{-1}$ or roughly 29.3%.

To confirm the failure of the ACSM prediction equation to predict oxygen uptake in this population, the actual oxygen uptake was regressed against the predicted oxygen uptake on both the treadmill and track. With respect to measured oxygen uptake on the treadmill, the ACSM prediction equation accounted for 62% of the variance whereas 55% of the variance was accounted for with respect to the measured oxygen uptake during track walking (Figures 4.3 and 4.4, respectively). The equations for predicting oxygen uptake on the treadmill and track from the ACSM prediction equation are as follows:

$$\text{Pred. } VO_{2\,TM} = 1.87\ _{\text{ACSM Pred.}} - 6.25,\ \text{SEE } 1.67$$

$$\text{Pred. } VO_{2\,TR} = 2.65\ _{\text{ACSM Pred.}} - 14.48,\ \text{SEE } 2.78$$

Where: $VO_2 = ml \bullet kg^{-1} \bullet min^{-1}$

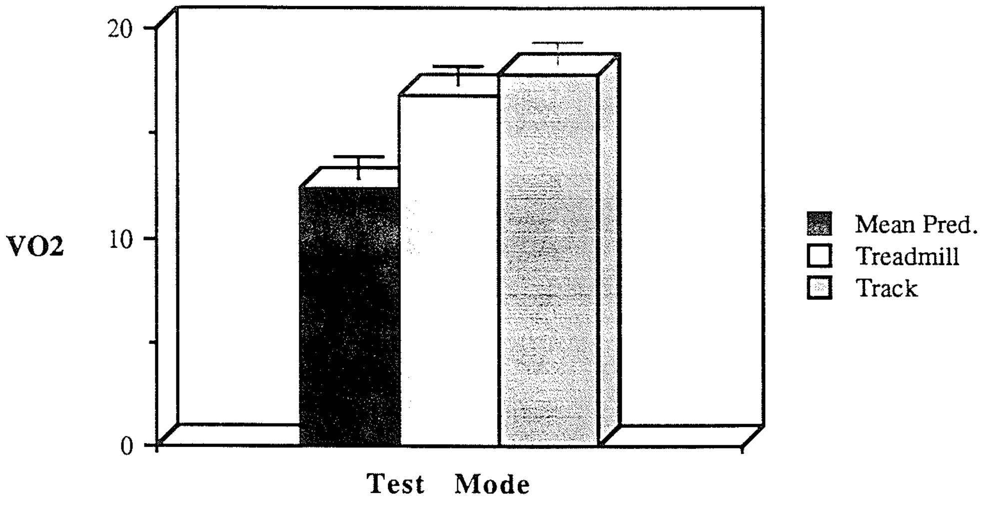

Figure 4.2- Graphical depiction of ACSM predicted versus actual measured VO$_2$ on the treadmill and track
KEY: VO$_2$ (oxygen uptake in ml•kg^{-1}•min^{-1}), Mean Pred. (average predicted oxygen uptake), Treadmill (measured oxygen uptake on the treadmill), Track (measured oxygen uptake on the track).

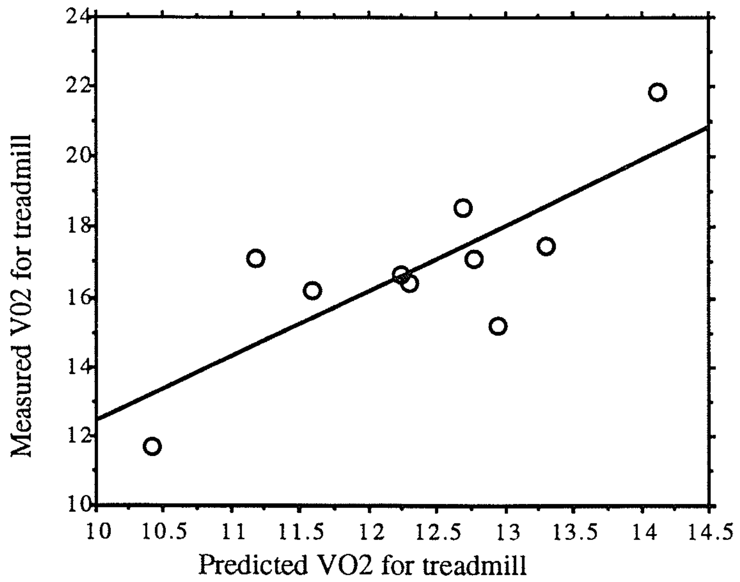

Figure 4.3- Linear regression of ACSM predicted treadmill VO$_2$ versus actual measured treadmill VO$_2$ (n=10)
Note: All V0$_2$ values are in ml•kg-1•min-1

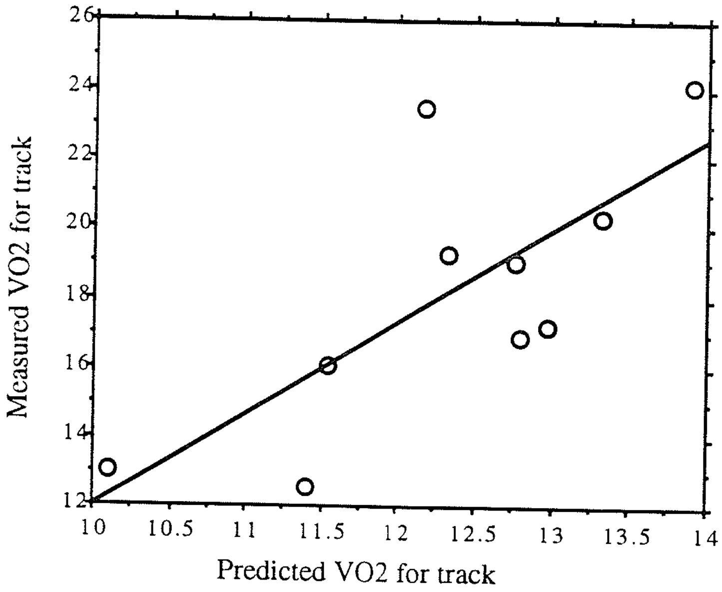

Figure 4.4- Linear regression of ACSM predicted track VO_2 versus actual measured track VO_2 (n=10)
Note: All VO_2 values are in ml•kg-1•min-1

5.0 Predictors of Oxygen Uptake

To determine the single best predictor of oxygen uptake, all variables were regressed against oxygen uptake on the track. Forearm girth showed the highest overall coefficient of variation (r^2=.68) followed by fat free mass (r^2=.66). The relationship between FFM and oxygen uptake on the track is depicted in Figure 4.5. Stepwise regression was then used to determine the best set of variables. When FFM was entered first, accounting for 66% of the explained variance, walking velocity on the track became the second and final variable. This accounted for an additional 19% of the explained variance, for a total of 85% (r^2=.85).

Table 4.7. Simple regression to predict oxygen uptake during track walking (n=10)

Variable	r2	SEE	p
Fat Free Mass (kg)	0.66	2.40	<0.01
Mass (kg)	0.62	2.56	0.01
Stature (cm)	0.66	2.43	0.01
Treadmill velocity (mph)	0.63	2.53	0.01
Measured V02 on treadmill	0.44	3.11	0.04
Age (yrs)	0.23	3.64	0.16

Note: Measured VO2 on treadmill in relative terms (ml•kg-1•min-1), SEE (standard error of estimate)

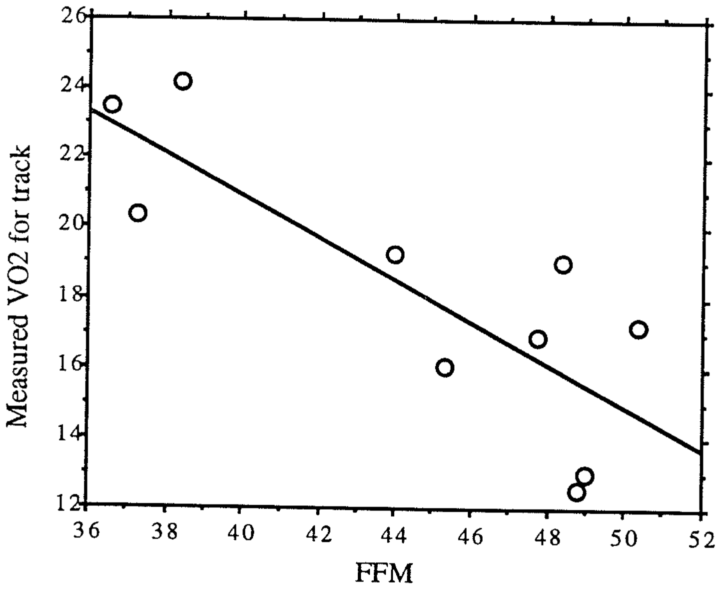

Figure 4.5- Linear regression of fat free mass to predict oxygen uptake during track walking
KEY: Measured oxygen uptake on the track in ml•kg-1•min-1), FFM (fat free mass in kg.)

Table 4.8. Stepwise regression to construct model predicting oxygen uptake during track walking

Step No. 1 Variable Entered : Fat Free Mass

r	r^2	SEE
0.81	0.66	2.40

(Last Step) Step No. 2. Variable Entered: Treadmill Waking Velocity

r	r^2	SEE
0.92	0.85	1.74

Variables in Equation

Variable	Coefficient
Intercept	20.203
Treadmill Walking Velocity	3.014
FFM	-0.407

Note: $V0_{2TR} = 20.203 + 3.014 \bullet V_{TM} - 0.407 \bullet FFM$

5.0 Age-related Trends

To determine whether there were any age-related effects on the variables measured, all variables were regressed against age. Oxygen uptake on the treadmill normalized for body weight was the only variable demonstrating a correlation with age ($r=.79$, $r^2=.62$, $p<0.01$).

Chapter 5

DISCUSSION

Introduction

The primary objective of this study was to determine the repeatability of a low intensity steady state walking test on the track and treadmill in an elderly female population. A second objective was to assess the generalizability of oxygen uptake measures on the treadmill to measures overground at the same velocity. Finally, the ability of the ACSM prediction equation to accurately reflect measured oxygen uptake during like measures on the track and treadmill was assessed. Three hypotheses were specified as a basis for examining differences between the oxygen cost of walking on the treadmill and track and the effect of age-related functional changes on the ability to predict oxygen uptake during low intensity, steady state walking. It was hypothesized that measures of oxygen uptake on the treadmill would be more repeatable than on the track when tested on repeat measures. Additionally, the oxygen cost of walking on the treadmill would be less than like measures on the track. Finally, it was hypothesized that the ACSM prediction equation would underestimate the oxygen uptake for elderly subjects during low intensity walking on the track and treadmill.

The rationale for this study was governed by two basic premises that have been extensively investigated. First, that regular participation in continuous activity at 70-80% of maximal heart rate leads to a reduction of risk factors that predispose one to heart disease. Exercise at this intensity, although known to be beneficial, is likely not suitable for an aging population. There is increasing evidence, however, that physical activity of low-to-moderate intensity can also decrease the risk of cardiovascular disease, despite a less profound effect on cardiovascular fitness (Girandola, 1976; Leaf et al., 1989). Second, to assess the contribution of low intensity activity to the abatement of cardiovascular risk factors it is essential to quantify the oxygen cost of the activity (Sallis et al., 1986; Roy et al., 1992). Direct measurement of oxygen uptake through gas exchange variables, although accurate, is neither manageable with large sample sizes, nor cost effective (McConnell, Foster, Conlin & Thompson, 1991). The use of a prediction equation would be more convenient during field tests that employ large sample sizes, as well as being considerably more cost effective. Functional changes associated with the aging process may, however, render these prediction equations inaccurate in older subjects.

Ten women between the ages of 59 and 73 were studied (mean = 65.4 yrs.). Mean values for height, mass, body mass index, sum of five skinfolds, waist to hip ratio and sum of two trunk skinfolds were compared to widely accepted percentile ranks (Canada Fitness Survey, 1981). The study group did not grossly differ from the compared norms for 60-69 year olds, with a mean study group percentile rank of 57.5. It should be noted at this point that no percentile ranks are available for muscle mass. At present no validated equation exists to estimate the muscle mass in an elderly female population. The equation of Martin et al. (1990, Appendix #2), although providing the best estimate of muscle mass for old men, is confounded by the higher adiposity of the women in this study and thus the potential for erroneous results does exist .

A between-trial comparison revealed that the first hypothesis of the present study was not supported since both the track and treadmill tests proved repeatable (Table 4.4). Normalizing track test velocities by means of a physiologic parameter (50% HRR) revealed an non-significant between-measures difference in velocity of only 0.05 mph. Additionally, repeatability of oxygen uptake values between the first and second track tests was evidenced by a between measures difference in oxygen uptake of 1.55 ml/kg/min. Since both treadmill velocities were matched to the velocity of the second track test, between means test comparison of mean velocities is not possible. Test repeatability was assessed, however, by a comparison of heart rates between trials. Heart rates were also proven to be repeatable, with a between test difference of only 1.2 bpm. Oxygen uptake values on the treadmill also proved to be repeatable with a between trial difference of only 0.09 $ml•kg^{-1}•min^{-1}$.

Although both the track and treadmill protocols were repeatable and no significant difference between track and treadmill mean oxygen uptake values was observed, measures on the treadmill displayed less between-trial difference and lower standard deviations (Table 4.4). Although minimal, this suggests some inherent capacity of the treadmill to exert stabilizing effects on the measures acquired in the present study. Walking at a low intensity steady state may also have accentuated any stabilizing effects associated with treadmill locomotion. Possible explanations for the larger between-trial difference and standard deviation of the track measures may be explained, in part, by subtle differences in the mechanical limitations imposed by the oxygen collection apparatus.

Although efforts were made to ensure standardized procedures for gas collection were followed, small differences in the subjects response to the collection apparatus may be reflected in the results. Additionally, during track walking the subjects were asked to remain within a target heart range and an alarm went off when they strayed from the appointed range. This invariably resulted in an exaggerated oscilatory pattern of walking velocity which would be reflected in the measurements and would not likely be exactly the same between trials.

From the data previously discussed, the use of a motor driven treadmill for research purposes enables better replication of results and provides a testing environment whereby metabolic measurements can be readily obtained, without disrupting the test, and consequently maximizing internal validity. Possible explanations for the repeatability of treadmill measures may lie in an increased capacity to provide fixed, stable workloads in conjunction with the low level of skill required to walk on a treadmill (Erickson et al., 1945). All workloads in the present study were subject-specific with fixed measurement procedures utilized in all cases. As discussed by Kirby (1986), the interval for subsequent testing may be as long as four weeks or as brief as 15 minutes without much loss of test reliability. It would then follow that utilizing a test/retest design with a between test lag of two weeks also contributed to the repeatability inherent with treadmill locomotion.

It has been previously shown that kinematic and gait parameters on the treadmill are subject to habituation and consequently subjects should be previously habituated prior any testing. Additionally, any measures should not be taken within the first two minutes of performance (Wall and Charteris, 1981). The possibility of habituation affecting the present investigation was minimized in three ways. First, all but one of the subjects were members of the Kinsmen Reh-Fit Centre, a wellness facility which uses a treadmill for regularly scheduled graded exercise tolerance tests on its members. Second, subjects were introduced to treadmill walking and the gas analysis apparatus during an introductory session which gathered the subjects in pairs at the testing site. Finally, during the actual testing, metabolic measurements were taken during the last two minutes of a ten minute steady state walk, thereby, minimizing the likelihood of habituation or neural ventilatory drive affecting any testing measures (Casey, Duffin, Kelsey & McAvoy, 1987; Wall & Charteris, 1981).

Substantiating the repeatability of the track and treadmill protocols enabled combining of repeat measures and thereby allowing a between-mean comparison of the track and treadmill protocols. This decreased the effects of measurement variability, as well any inherent experimental variability, thereby increasing the strength of the measures. A consistent, yet non-significant, difference between the oxygen requirement for track and treadmill walking was disclosed in the present study (Table 4.6), thus the second hypothesis was not supported. It was also shown that the generalizability between the treadmill and track oxygen uptake demonstrated no learning affect (Table 4.6). Though an average difference of approximately 8% does exist between the oxygen cost of walking on the treadmill and track, based on the current study, the oxygen requirements of low intensity steady state walking on the treadmill are generalizable to corresponding populations walking on the track at similar velocities.

Although direct measurement of oxygen uptake from gas analysis is widely accepted as the most accurate measure of exercise tolerance, many laboratories do not have the capacity to measure oxygen consumption during various field activities. The use of indirect estimates derived from velocities measured on treadmills is now commonplace in ergonomic and physiologic studies which examine large sample sizes, due primarily to the mechanical simplicity, need for fewer highly trained personnel, and subsequently, the overall cost effectiveness. External validity, or the ability to generalize between treadmill and overground ambulation has been the subject of much debate. In the present study, the oxygen uptake between low intensity steady state walking on the track and treadmill were directly measured and statistically compared revealing non-significant differences. Any potential differences between track and treadmill walking were minimized by properly habituating the subjects and using standardized equipment and procedures, thus the treadmill test would more closely simulate horizontal walking on a hard surface.

Three forces act between the subject and the environment during walking: gravitational force; air friction; and the force exerted by the feet. During level walking, such as conducted in the present study, the mean power against the gravitational force is zero. Although the air resistance during walking on an indoor track would be small, there is potential for this difference in air friction to be represented in the oxygen cost of the activity. According to Webb et al. (1988) air resistance at speeds equivalent to the present study would be estimated at 3 Watts, which may affect the oxygen cost. Another possible explanation for the slightly lower oxygen cost of treadmill walking may lie in subtle differences between the treadmill and track walking surfaces. If the rubberized surface of the track differed appreciably in absorbency qualities from the treadmill walking surface a discrepancy between the oxygen cost of track and treadmill walking would result. The softer surface of the track would likely result in a higher oxygen cost at equivalent speeds. As suggested by Williams et al. (1992), the oxygen cost of walking on the softer surface would result in a higher oxygen cost. Other possible explanations for the difference in oxygen cost between the track and treadmill may differences in visual and auditory information. Visual information and, to a lesser extent, auditory information aid in maintaining equilibrium and stability during locomotion. According to Van Ingen Schenau (1980), this may result in differences in regulation of the movement pattern resulting in differences in kinematics and/or oxygen consumption.

The fact that oxygen uptake values on the treadmill and track protocols proved to be repeatable and between mean comparison of the two protocols revealed no significant difference, reaffirms that measures on the treadmill are generalizable to corresponding measures, utilizing the same subjects on the track. Although previous studies examining differences in the oxygen cost of overground and treadmill walking have yielded a divergence of findings, the 8% higher oxygen uptake on the track as compared to the treadmill is in agreement with the findings of others (Daniels et al., 1953; Woolley & Winter, 1979; Pearce et al., 1983). In this study, oxygen uptake measured on a motor-driven belt at a low intensity steady state, was lower than that measured on the track for women age 60 years or greater. Future studies incorporating larger sample sizes walking over a range of low intensities should further clarify this issue. The paucity of studies on older populations, specifically women, examining the difference in oxygen consumption between overground and treadmill walking makes comparison with other studies difficult.

The American College of Sports Medicine equation to predict oxygen uptake during horizontal walking is widely accepted as a viable alternative to direct measurement of oxygen uptake between speeds of 1.9 to 3.7 mph. In the present study, using velocities between 2.5 and 4.0, the prediction equation was found to significantly underestimate oxygen uptake on both the track and treadmill in this specific sample, thereby supporting the third hypothesis (Table 4.5 & 4.6; Figure 4.2, 4.3, & 4.4). This represents a mean underestimation of 5.2 $ml\bullet kg^{-1}\bullet min^{-1}$ or approximately 29.3%. The results of the present study are consistent with other studies that used true steady state measures (Wilkie et al., 1987, Montoye et al., 1985). During graded exercise testing, such as the Bruce Protocol, a true steady state may not be attained in certain populations, thus affecting prediction of the oxygen cost of the work. By using a low intensity steady state workload performed for ten minutes it is likely that subjects in the present study did achieve a true steady state thereby maximizing the efficacy of estimating the oxygen cost of the activity. The reasons for the failure of the ACSM equation to accurately predict the oxygen cost of walking in this study were examined by regression analysis of the predictor variables.

All variables were assessed against oxygen uptake on the track. The single best predictor was found to be forearm girth (r^2=.68) followed by fat free mass (FFM, r^2=.66). Although speculative, the current study suggests that forearm girth may be an indicator of fat free mass in elderly women. Age-related changes in fat free mass, such as muscle and bone, are well documented and play a vital role in structure and function in the elderly (Kaneko et al., 1991, Pearson et al., 1985). The exact mechanisms by which changes in fat free mass alter oxygen uptake kinetics, rendering prediction inaccurate in this investigation are unknown, however, there is much anecdotal information to venture an explanation.

According to the American College of Sports Medicine (1988), the ability of the body to take up and utilize oxygen is contingent on pulmonary ventilation, diffusion of oxygen from the lung alveoli to the pulmonary capillary bed, cardiac performance, blood redistribution to muscular vascular beds and oxygen extraction at the skeletal muscle. All these indicies, which may affect the oxygen transport and consequently the prediction of oxygen uptake, are subject to age-related changes mediated by both structure and function. From the data previously reviewed age-related morphological and physiologic changes in the lung, decrements in cardiac performance, changes in the systemic vascular system and postural changes are all well documented (Shephard, 1988a; Lakatta et al, 1987; Landin et. al, 1985). The ACSM equation that predicts the oxygen cost of walking was derived from the physiologic assumption that oxygen consumption, above basal, should vary directly with velocity and the product of velocity and elevation (Ross et al., 1986). Based on this investigation this single regression model is subject specific and thus is limited in its external validity.

The majority of oxygen utilized by the body can be accounted for in the metabolically active vital organs and skeletal muscle. Bone and fat use relatively little oxygen and the combined mass of the vital organs in healthy individuals is not likely to change much with age. It then follows that the tissue most suspect to reflect age-related changes and subsequently the tissue that exerts the greatest influence on oxygen uptake would be muscle mass, or a related aspect such as fat free mass. One might also postulate that, based on the small sample in current investigation, the age-related structural and functional changes in the cardiorespiratory and musculoskeletal systems of the elderly act synergistically on both the oxygen transport and the musculoskeletal systems and thus render a global prediction equation not applicable to the women in this study. This investigation demonstrated a significant negative relationship between the oxygen cost of walking on the track and FFM (r^2=.66, Figure 4.5). One may expect that a higher FFM would have resulted in more oxygen consumed for a given activity due to the higher metabolically active FFM. If the fitness levels of the subjects were appreciably different this relationship would not hold true. The present investigation was concerned with low intensity workloads and did not measure physical work capacity or maximal oxygen uptake. It is therefore only speculative, however likely, that the more fit individual would have had a higher FFM. Further to this, it is likely the more fit individual would demonstrate a more "normal" pattern of gait as opposed to the guarded patterns common in the elderly subject with a lower habitual activity and a concurrent decrement in physical work capacity. The higher fitness would likely result in a more efficient pattern of walking and this would be reflected in the oxygen cost of the activity. The ACSM equation, which makes no adjustment for age-related structural and functional changes, would not be applicable to a population of elderly women. Further investigation into the inter-relationship between forearm girth, FFM and the oxygen cost of waking across a variety of populations will clarify the role these variables play in any prediction model.

Age-related trends in all variables were examined by simple regression. Based on the subjects utilized in the current investigation, the only variable showing an age-related effect was VO_2 on the treadmill. Although other investigators have demonstrated age-related structural and functional changes in many of the variables that exert effects on the oxygen cost of physical activity, the current investigation did not demonstrate similar trends. Comparisons through simple regression, such as the age-related comparisons in this study, are highly sample-specific and are therefore subject to errors exploited through the uniqueness of the sample. The subjects utilized in this study although representative of healthy older women, were likely more habitually active than their peers. The fact that these subjects showed few age-related trends further supports the notion that "normal" or active aging can offset many of the deleterious effects previously associated with the aging process.

The present investigation did not measure any biomechanical parameters associated with walking. Though such parameters were not measured in the present study it is likely that gait patterns in this population of older women would be more variable than in a younger population. A normal pattern of gait requires a highly coordinated integration of the nervous, muscular, skeletal, circulatory and respiratory systems (Imms & Edholm, 1981). The deterioration of postural control associated with aging manifests itself as a guarded or prehensile pattern of gait (Stelmach & Worringham, 1985). Older individuals typically spend a longer time in the stance phase and a shorter time in the swing phase of walking than do younger individuals. This increase in the variability of gait parameters is associated with a less efficient pattern of walking and would thus increase the oxygen cost of the activity.

The present investigation demonstrated only minor age-related effects in the variables measured. Larger sample sizes including subjects with a wider range of habitual activity levels would increase the likelihood of disclosing an age-related effects. This study demonstrated that the ACSM equation to predict the oxygen cost of horizontal steady state walking significantly underestimated oxygen uptake and was, therefore, invalid in older females. Though a paucity of comparable studies makes comparison difficult, this investigation suggests that the ACSM equation, which makes no compensations for age, is in need of including other variables such as FFM or making a systematic age adjustment.

To construct a model to predict oxygen uptake in the present population, fat free mass was entered into stepwise regression (r^2=.66) followed by walking velocity on the track (r^2=.85). This disclosed a final prediction model of:

Pred. $VO_{2\ TR} = 20.203 + 3.014 \bullet V_{TR} - 0.407 \bullet FFM$ (SEE =1.74 $ml \bullet kg^{-1} \bullet min^{-1}$)

The equation developed in this study is suitable to an elderly population for the following reasons. First, age-related declines in fat free mass and the concomitant loss of function are well documented in the literature. Age-related increases in the variability of gait parameters and consequently the efficiency of walking are well documented in the literature. These functional and structural changes are likely to have deleterious effects on the oxygen transport system in addition to the mechanics of ambulation. This would jeopardize the external validity of the equation by increasing errors that arise from population differences. It then follows that any regression model should include variables that will account for individual and population differences. Secondly, the velocity of walking has been widely shown to be the primary determinant of the oxygen cost of walking. The present study, using only a single walking velocity for each subject, did not find walking velocity to be the variable with the highest association to oxygen cost. Other investigators who utilized an array of velocities for each subject have clearly demonstrated walking velocity to be the primary determinant of the oxygen cost of walking (Ross & Jackson, 1986; Bubb et al., 1985). This is consistent with the basic premise of the ACSM equation, specifically the oxygen consumption during steady state walking is dependent on the walking velocity, multiplied by some constant. Based on the results of this study it is prudent to suggest that FFM does in fact exert an influence on oxygen uptake kinetics, thus rendering the ACSM equation invalid because it does not account for age-related changes. To determine whether age-related functional changes exert a systematic influence on oxygen uptake kinetics, larger sample sizes, covering a broader age range of subjects should be employed.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this study was to assess the repeatability of oxygen uptake during like measures on the track and treadmill. Additionally, the generalizability of oxygen uptake measures during steady state walking on a motor-driven treadmill to corresponding measures obtained during overground walking. Finally, oxygen uptake values measured directly were compared to corresponding values estimated using the ACSM prediction equation. It was hypothesized that the oxygen uptake measures would be more repeatable on the track than on the treadmill when tested on repeat measures. It was also hypothesized that the oxygen cost for treadmill walking would be less than that of walking on the track at the same velocity. Finally, oxygen uptake values estimated using the ACSM equation would not reflect the actual oxygen uptake in elderly subjects walking at steady state on the treadmill and track.

A review of literature showed that age-related changes in the morphology and physiology of the cardiopulmonary and musculoskeletal systems as might be expected to exert functional changes resulting in altered oxygen uptake kinetics. The deleterious age-related effects on the variables affecting the kinetics of oxygen uptake could consequently render prediction of oxygen uptake by the ACSM equation inaccurate in this population since no age-related adjustments are incorporated in this prediction equation.

A number of conclusions can be drawn from this study, specifically:

1. The subjects in this study, although obtained by recruitment, did not grossly differ from an average sample of 60-69 year old women, compared to norms from the Canada Fitness Survey (1981). A mean percentile rank of 57.5 with the following percentile ranks was disclosed: height (65.0), mass (50.0), body mass index (65.0), sum of five skinfolds (60.6), waist to hip ratio (55.0) and sum of two trunk skinfolds (50.0).

2. Between trial comparison by t-test revealed that all measures of velocity, oxygen uptake and heart rate on the track and treadmill were repeatable. Though non-significant, measures on the treadmill were slightly less variable than measures on the track.

3. Comparison of between protocol oxygen uptake by t-test and regression analysis revealed that the measures of oxygen uptake on the treadmill accurately reflected the oxygen uptake during track walking at corresponding velocities. Though non-significant measures on the track did demonstrate an 8% higher oxygen cost at the same velocity.

4. The American College of Sports Medicine prediction equation was found to be invalid in this population, significantly underestimating the oxygen requirements of walking at low intensity steady state.

5. Using regression analysis, the single best predictor of oxygen uptake on the track was forearm girth (r^2=.68) followed FFM (r^2=.66). In an attempt to construct a new prediction model, stepwise regression was used to determine the best two variable combination. Fat free mass was entered into stepwise regression

(r^2=.66) with treadmill walking velocity as the final variable (r^2=.85). This reveals a final prediction model of:

Pred. $VO_{2\,TR}$= 20.203 + 3.014•V_{TM} - .407•FFM (SEE 1.74 ml•kg $^{-1}$•min^{-1})

6. The only variable showing an age-related trend was the average oxygen uptake on the treadmill (r^2=.62).

Recommendations

Based on the results of the present study the following general recommendations are made:

1. For experimental purposes, oxygen uptake measurements during treadmill walking are generalizable to overground walking at the same velocity. Further investigations should use larger sample sizes, with broader age ranges and walking at a variety of velocities to examine the age-related difference in oxygen cost and the repeatability between treadmill and overground walking.

2. Future equations developed to predict oxygen requirements of walking should take into consideration the effects of aging on fat free mass. By examining the relationship between age-related changes in the lean tissues of the body and the biomechanical variables that affect walking efficiency, a better understanding of the oxygen requirements of walking in elderly populations will be gained. Models employing appropriate adjustments for aging will predict oxygen uptake more accurately in elderly populations.

Appendix #1

Determination of Oxygen Uptake (ACSM, 1988)

The determination of maximal VO_2 can be calculated from either cardiovascular or respiratory parameters. For example, a common relationship is:

$$VO_2 = Q \bullet (a\text{-}\bar{v}\ O_2 \text{ difference}) \qquad [1]$$

in which Q is cardiac output (in L/min) and $a\text{-}\bar{v}\ O_2$ is difference in oxygen concentration between arterial blood and mixed venous blood. The result is expressed as a fraction (e.g., 5 ml 0_2/100 ml blood = 0.05). Although this relationship is a good example of the interplay between the cardiovascular and respiratory systems, it does little to help in the calculation of VO_2 because neither Q nor $a\text{-}\bar{v}$ 0_2 difference are readily measured noninvasively.

A more helpful relationship is:

$$VO_2 = (VI \bullet FI\ O_2) - (VE \bullet FE\ O_2) \qquad [2]$$

in which VI is the rate at which air is inspired, $FI\ O_2$ is the fraction of oxygen in the inspired air, VE is the rate at which air is expired, and $FE\ O_2$ is the fraction of oxygen in the expired air. This, VO_2 or the rate of oxygen consumption simply represents the difference between the rate of oxygen inspiration and the rate of oxygen expiration. Recall that VI only equals VE when the respiratory exchange ratio, $R = VCO_2/VO_2$, equals 1.00 (i.e., when the rate of production of CO_2 is equal to the rate of consumption of O_2). In this simplified case an only in this case can equation be rewritten

$$VO_2 = VE \bullet (FI\ O_2 - FE\ O_2) \quad [3]$$

More generally, VO_2 can be calculated from equation 2 by one of two methods. First, because the concentration or fraction of oxygen in inspired air ($FI\ O_2 = 20.93\% = 0.2093$) is known, VO_2 can be calculated using two volume flow meters to measure the inspired and expired volume flow rates and an oxygen analyzer to measure oxygen concentration in inspired air. The four factors to the right of the equal sign in equation 2 would be known and VO_2 could be calculated.

More typically, VO_2 is calculated as follows. VE and $FE\ O_2$ are measured form expired air with a volume flow meter and an oxygen analyzer, respectively. $FI\ O_2$ is known and equals 20.93% or 0.0293. VI is then calculated from the following relationship called the Haldane transform. Because nitrogen is neither produced nor consumed to any great extent during metabolism VN_2, the rate of nitrogen production or consumption, is equal to zero, or

$$VN_2 = (VI \bullet FI\ N_2) - (VE \bullet FE\ N_2) \quad [4]$$

Therefore,

$$VI \bullet FI\ N_2 = VE \bullet FE\ N_2 \quad [5]$$

or

$$VI = (VE \bullet FE\ N_2)/FI\ N_2 \qquad [6]$$

The fraction of N_2 in inspired air (FI N_2) is known and is equal to 79.04% or 0.7904. The fraction of N_2 in the expired (FE N_2) can be calculated from the relationship,

$$FE\ N_2 = 1.0000 - FE\ 0_2 - FE\ CO_2 \qquad [7]$$

as long as dry gases are analyzed. Note that the difference in concentration of nitrogen in inspired and expired air is a consequence of the differences in the inspiratory and expiratory volume flow rates and not of the production or consumption of nitrogen by the body. For example, if more oxygen is consumed than carbon dioxide is produced ($R < 1.00$), VI will be greater than VE and nitrogen will occupy a greater fraction of the expiratory volume than that of the inspiratory volume (FE N_2 > FI N_2). By using equation 7 and the value for FI N_2, we can calculate VI in equation 6:

$$VI = [VE \bullet (1.0000 - FE\ O_2 - FE\ CO_2)]/0.7904 \qquad [8]$$

By recalling equation 2,

$$VO_2 = (VI \bullet FI\ O_2) - (VE \bullet FE\ O_2) \qquad [2]$$

we can solve for VO_2 by substituting equation 8 and the value for FI O_2 (0.2093) into equation 2:

$$VO_2 = VE \bullet [0.265 \bullet (1.0000 - FE\ O_2 - FE\ CO_2) - FE\ O_2 \qquad [9]$$

The value contained within the brackets in equation 9 is the True O_2 and is the fraction of oxygen consumed for any VE. By inspecting equation 9, we see that VO_2 can be calculated by using a volume flow meter to measure VE and by gas analyzers to measure the fractions of oxygen and carbon dioxide in expired air (FE O_2 and $FECO_2$, respectively).

Whereas VE is measured under ambient conditions, i.e., Ambient Temperature, Pressure and Saturated with water vapor (ATPS), in metabolic calculation VE must be expressed relative to Standard conditions of Temperature (273^0 K, Pressure (760 mm Hg), and Dry (i.e., no water vapor) (STPD) so that these flow rates may be compared in environmental conditions that may vary relative to altitude, heat, and humidity. VE(ATPS) may be converted to VE(STPD) as follows:

$$VE(STPD) = VE(ATPS) \bullet$$
$$[(PB - WVP)/760 \text{ mm Hg}] \bullet [273^0K/(273^0K + TG)] \qquad [10]$$

in which PB is ambient barometric pressure and WVP is the water vapor pressure at the gas temperature (TG) in the volume flow meter. TG is presented in ^0C and WVP can be found in standard tables. Body temperature is at 37^0 C

Appendix #2

Determination of Muscle Mass (Martin et al., 1989)

$$MM = [STAT \bullet (0.0553 \bullet CTG^2 + 0.0987 \bullet FG^2 + 0.0331 \bullet CCG^2) - 2445]/1000$$

Where: MM is muscle mass (kg), STAT is height in (cm), CTG is mid-thigh girth corrected for the front thigh skinfold thickness (cm), FG is forearm girth (cm), and CCG is the calf girth corrected for the medial calf skinfold thickness (cm).

$$CTG = (\text{mid-thigh girth}) - [(3.1416) \bullet (\text{front thigh skinfold})/10]$$

$$CCG = (\text{calf girth}) - [(3.1416) \bullet (\text{medial calf skinfold})/10]$$

% Muscle mass can then be calculated as follows:

$$\%MM = (MM/\text{mass}) \bullet 100$$

Appendix #3

Medical History and Physical Activity Questionnaire

Sport & Exercise Sciences Research Institute
University of Manitoba

Medical History and Physical Activity Questionnaire

Please fill this form out as completely as possible. Thank you

Date:________________________
(month, day, year)

Participant:____
Last Name First Name Initial

Birth Date:___________________
(month, day, year)

MEDICAL HISTORY

Please circle the correct response.

1. Are you presently taking any prescribed medication? Y N

   If so, please indicate which medication and for what purpose it is being taken.

   ____

   ____

   ____

2. Have you ever felt any chest pain upon exertion? Y N

   If yes, please indicate what activity was being done at the time and what was done about the chest pain.

   ____

   ____

   ____

3. Do you have any ankle, knee or hip problems that would not allow you to walk at a brisk pace? Y N
4. Do you have asthma or any other lung disfunctions? Y N

   If yes, is the problem aggravated with exertion.

   ____

   ____

   ____

PHYSICAL ACTIVITY

1. Do you consider yourself physically active? Y N

   If so, what type of activities do you participate and how often are these activities done.

   ____

   ____

   ____

2. If you are not physically active now, were you in the past? Y N

   If yes, please indicate what activities and how often you participated in them.

   ____

   ____

   ____

Appendix #4

Informed Consent

Sport & Exercise Sciences Research Institute
University of Manitoba

Description of Research Project
Information to Participant and Consent Form

The Generalizability of Treadmill to Overground Measures of Oxygen Uptake and the Efficacy of the American College of Sports Medicine Prediction Equation in Older Women

Investigator: Mike Brennan, B.S.
Faculty of Physical Education and Recreation
Studies, Sport & Exercise Sciences Research Institute,
University of Manitoba

EXPLANATION OF STUDY

This project is the preliminary phase of a multi-disciplinary study designed to determine the minimum amount of walking necessary to decrease the metabolic risk factors for cardiovascular disease (CVD). To assess the contribution of the walking program in lowering certain risk factors for cardiovascular disease it is important to be able to accurately quantify the oxygen consumed. Due to special considerations pertaining to an adult population the equations available to predict oxygen uptake during walking may not be accurate when referring to an adult population.

Purpose

The purpose of this study is to determine the relationship between the oxygen consumed during steady state treadmill and track walking and compare these values to those derived from a commonly used prediction equation. The repeatability of the track and treadmill tests will be assessed by repeat measures.

Methods and Procedures

Fifteen women aged 60 years and older will be recruited to take part in the study. The participants must be free of any cardiovascular, pulmonary or metabolic diseases that would preclude safe participation in the study. The testing will be conducted at the Sport and Exercise Sciences Research Institute at the University of Manitoba. It is recommended that you wear comfortable exercise clothing (ie. shorts/sweat pants and a T-shirt). You will be asked to abstain from food and caffeine for a minimum of three (3) hours prior to your scheduled test. We will ask that you limit your activity level to only activities of daily living on the days of the testing.

Screening

During your first visit to the laboratory you will be asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) and a short medical questionnaire. You will then be familiarized with the techniques and equipment that will be used throughout the study. A short walk on the treadmill while hooked up to the gas analysis equipment will also occur at this time. the total time required during this session will be approximately one-half hour.

You will be asked to return to the Sport and Exercise Sciences Research Institute for approximately one hour, on four more occasions. During each of these occasions you will perform a walking test on either the track or the treadmill (twice on each the track and treadmill). You will be asked to abstain from food and caffeine for at least three hours prior to the tests.

Treadmill Test

This test entails a five minute warm-up walk on the treadmill at 0% grade, followed by a 10 minute walk at the desired heart rate. The speed will be adjusted slightly to keep the steady state heart rate. You will be required to breathe through a mouthpiece for the final 2 minutes of the 10 minute walk. This will require your nose being plugged with a noseclip, so it will be necessary to breathe through your mouth. The expired gas will be collected in large balloons that will be carried beside you. Heart rate will be continuously monitored throughout the test. The total time required for this test will be less than one hour.

Track Test

This test will be conducted in the Max Bell Centre on a 200 metre oval track. The target heart rate that is walked at, along with the gas collection procedures will be the same as used in the track test. The total time required for this test will also be less than one hour.

RISKS

Due to the low intensity of the walking tests it is highly unlikely that injury or illness will result. Participants will be screened and the testing will be conducted only by qualified individuals. Potential risks include dizziness, fainting, leg cramps, nausea, chest discomfort and in extremely rare instances, abnormalities in heart rhythm. Should you feel and discomfort or pain during the testing you must immediately inform the tester so that the test can be terminated.

Signed ______________________

Witness ____________________

Date ________________________

Appendix B

Physical Activity Readiness
Questionnaire (PAR-Q)*

Appendix # 5

NAME OF PARTICIPANT ____________________

DATE ____________________

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (✓) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness appraisal. Tell your physician what questions you answered YES to on PAR-Q or present your PAR-Q copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity starting off easily and progressing gradually;
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM – a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort;
- A FITNESS APPRAISAL – the Canadian Standardized Test of Fitness (CSTF).

postpone

If you have a temporary minor illness, such as a common cold.

---

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE). Translation, reproduction and use in its entirety is encouraged. Modifications by written permission only. Not to be used for commercial advertising in order to solicit business from the public.
Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

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