VALIDATION OF THE PHYSICAL ACTIVITY INDEX (PAI) AS A MEASURE OF TOTAL ACTIVITY LOAD AND TOTAL KILOCALORIE EXPENDITURE DURING SUBMAXIMAL TREADMILL WALKING

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PURPOSE: The primary purposes of this investigation were to examine the validity of the Physical Activity Index (PAI) as, (a) a measure of total activity load (intensity of exercise x volume of exercise) and (b) as an estimate of total kilocalorie (kcal) expenditure during submaximal treadmill walking. A secondary purpose was to compare estimated kcal expenditure determined by the PAI prediction model to the estimated kcal expenditure determined by the SenseWear Pro Armband™. **METHODS:** Thirty-two recreationally active females (20.36 ± 1.27 years) participated in this study. Subjects participated in three counterbalanced submaximal walking bouts: low intensity (4.02 $km \cdot hr^{-1}$, 0% grade), moderate intensity (5.63 $km \cdot hr^{-1}$, 2.5% grade), and high intensity (7.24 $km \cdot hr^{-1}$, 5% grade). Each bout was separated by five min of rest. During each of the three exercise bouts, oxygen consumption (VO_2), rating of perceived exertion (RPE), pedometer step count, and kcal expenditure were measured. The PAI was calculated as the product of RPE and pedometer step count for each of the three, 10 minute bouts of treadmill walking. **RESULTS:** Concurrent validation of the PAI was established using VO_2 and heart rate (HR) as the criterion variables. Multiple regression analyses revealed a strong, positive relation between PAI score and VO_2 ($r = 0.92$) and HR ($r = 0.84$). Data were then used to develop a statistical model to estimate kcal expenditure using the PAI score as the predictor variable.

Model III.

Predicted kcal = 28.056 + 0.006 (PAI score) $\boldsymbol{p < 0.05}$**, SEE = 17.34, r = 0.80,** $\mathbf{r^2 = 0.64}$

Walking kcal expenditure predicted by Model III was highly correlated with measured kcal expenditure (r = 0.85). Similarly, kcal expenditure estimated by the SenseWear Pro Armband™ evidenced a strong, positive correlation with measured kcal expenditure (r = 0.83) when calculated across the three walking intensities. **CONCLUSION:** The development of a PAI using RPE and pedometer step count to estimate kcal expenditure may have significant public health implications. The PAI was found to be more accurate then the Armband method of estimating kcal expenditure and is a simple, unobtrusive and inexpensive tool which may be used to assess kcal expenditure in public health, clinical, and/or rehabilitation settings.

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I. INTRODUCTION

The purpose of this investigation was to develop and validate a Physical Activity Index (PAI) to estimate kilocalorie (kcal) expenditure during submaximal walking at varying intensities.

1.1 PHYSICAL ACTIVITY

Physical activity for improved health and well-being has become increasingly important as the United States population continues to increase in age and body weight. Public health recommendations have evolved from primarily emphasizing vigorous activity for cardiorespiratory fitness to including more moderate levels of activity for long term health benefits. Research indicates that for improved health and well-being, individuals should perform physical activity for at least 30 minutes on most, if not all, days of the week (CDC, 2006). It is also acknowledged that for most individuals, greater health benefits can be obtained by engaging in physical activity of comparatively more vigorous intensity and/or of longer duration (CDC, 2006).

Low levels of physical activity are a major risk factor for morbidity and mortality from all causes (AIHW, 2006). According to the World Heart Federation, physical inactivity increases the risk of hypertension by 30 percent and coronary heart disease by 22 percent (WHF, 2002). Furthermore, physical inactivity is a significant contributor to overweight and obesity and is associated with conditions and diseases such as: aneurysms, angina pectoris, atherosclerosis, back pain, heart attack, hemorrhoids, hypertension, hypercholesterolemia, osteoarthritis, osteoporosis, and type II diabetes (WHF, 2002).

Daily physical activity can help prevent health complications such as heart disease and stroke by increasing cardiac stroke volume, decreasing blood pressure, increasing high-density lipoprotein levels and lowering low-density lipoprotein levels (CDC, 2006). Optimizing each of these factors can provide additional benefits in decreasing the risk of heart disease. Physical activity also helps to reduce excess body fat, preserve or increase muscle mass, and improve the body's ability to use energy. When physical activity is combined with proper nutrition, it can help control body weight and prevent obesity, a major risk factor for many diseases.

1.2 SIGNIFICANCE OF OBESITY

A significant public health problem in the United States involves excess body weight. It is estimated that greater than 60 percent of adults in the United States are overweight, which is defined as a body mass index (BMI) of a least 25 kg/m^2. Moreover, in excess of 30 percent of adults are classified as obese (BMI $\geq$ 30 kg/m^2) (Flegal et al., 2002). These percentages have risen significantly over the past few decades, despite the emergence of surgical, pharmacotherapy, and behavioral interventions to address overweight and obesity among American adults (Kuczmarski et al., 1994).

Epidemiological evidence indicates that excess amounts of body weight contribute to health complications that increase mortality (Flegal et al., 2002). It is estimated that overweight and obesity contribute to approximately 325,000 deaths per year (Allison et al., 1999). Although one of the national health objectives for the year 2010 is to reduce the prevalence of obesity and its comorbidities, current data indicate that the prevalence of obesity is worsening rather than improving. This is a major concern for public health officials.

The significant increase in overweight and obesity among American adults is primarily caused by an excess kilocalorie (kcal) intake and/or lack of kcal expenditure (Wing, 1999). With respect to the latter, many American adults do not participate in the recommended amount of daily physical activity (30 minutes/day on most days of the week), despite its proven health benefits. In fact, more than 60% of American adults do not acquire adequate physical activity to promote health benefits (CDC, 2003). Moreover, 40% of adults are not physically active at all in their leisure time (ACSM, 2006).

1.3 PHYSICAL ACTIVITY INDEX

As a result of these population trends, several new physical activity intervention strategies have been created to address the issue of physical inactivity. Among these interventions is the use of pedometers to both promote physical activity adoption and adherence, as well as to track physical activity intervention outcomes. The present investigation focused on a proposed method to enhance the information provided by pedometers in assessing physical activity level. Specifically, the present research examined the development and validation of a Physical Activity Index (PAI) to measure the total activity load (i.e. volume of exercise x intensity of exercise) and associated kcal expenditure during varying walking intensities. For purposes of this investigation, the PAI was calculated as the product of pedometer step count and rating of perceived exertion (RPE) for a specific treadmill walking bout. This index score was then used as the predictor variable in a model that estimated kcal expenditure for walking exercise.

Current exercise recommendations suggest that to lose weight and to prevent weight regain, one should exercise approximately 300 minutes/week at a moderate intensity (Jakicic, 2001). This recommendation primarily focuses on the volume of physical activity undertaken. However, the influence of varying levels of walking intensity on kcal expenditure is more difficult to quantify in free-living environments. Thus, it was proposed that by monitoring both the volume (i.e. steps) and intensity (i.e. RPE) during walking exercise, one can more accurately measure the total activity load and from this index value estimate associated kcal expenditure. From preliminary research, this index score has been shown to have a positive relation with kcal expenditure ($r = 0.69$) during selected walking and running treadmill speeds (Weary et al., 2006).

1.4 PEDOMETERS

Due to the increase in the number of physical activity recommendations, physical activity monitors, such as pedometers, have become increasingly popular. Pedometers are inexpensive, light-weight, and unobtrusive tools that measure physical activity by responding to vertical accelerations of the hip during gait cycles (Schneider, 2004). Pedometers typically include a horizontal, spring suspended lever arm that moves up and down with normal ambulation (i.e. walking or running). An electrical circuit closes with each movement detected and an accumulated step count is displayed digitally on a feedback screen. Pedometers do not however, record velocity or intensity of movement, restricting their use to measuring only total accumulated steps/day (President's Challenge Report, 2006).

Pedometers have been found to be a valid method for assessing ambulatory modes of physical activity such as walking and climbing stairs (Tudor-Locke et al., 2002). When comparing pedometers to others methods of physical activity monitoring, Tudor-Locke and colleagues (2002) found a high correlation between pedometer step counts and accelerometer counts ($r = 0.86$), physical activity observation ($r = 0.82$), energy expenditure ($r = 0.68$), and self report physical activity questionnaires ($r = 0.33$).

Studies have shown that pedometers are most accurate at measuring steps taken (Bassett et al., 1996; Hendelman, et al., 2000), less accurate at estimating distance traveled (Bassett et al., 1996; Hendelman et al., 2000) and even less accurate at estimating kcal expenditure (Bassett et al., 2000). For these reasons, it has been recommended that steps taken, or steps/day, be universally adopted as a standard unit of measurement for collecting, reporting, and interpreting pedometer data (Rowlands et al., 1997; Tudor-Locke & Myers, 2001).

Recent advances in technology and quality control have led to improvements in the reliability and validity of pedometers. In a review of five commercially available electronic pedometers, Bassett et al. (1996) reported acceptable results for most of the monitors examined, with the Yamax Digi-Walker (Yamax Inc., Tokyo, Japan) exhibiting the highest reliability and validity. The Digi-Walker model provided the most accurate assessment of step counts and distance walked for each of the walking paces tested (i.e. 3.22 to 6.43 $km \cdot hr^{-1}$). Thus, the Yamax Digi-Walker SW-701™ will be used in the present investigation to measure step counts.

The National Institutes of Health recommends the use of pedometers as a means to ensure 10,000 steps a day for optimal health (NIH, 2005). However, while pedometers accurately measure motion of the hip flexor, they do not accurately measure exercise intensity. So although pedometers can be useful tools, they do not account for differences in intensity of walking exercise, and thus do not accurately measure kcal expenditure. Because pedometers do not account for intra- and inter-individual differences in exercise intensity, it is proposed that an adaptation to the pedometer step count system is needed to account for this methodological limitation. As such, we propose to complement pedometer step counts with RPE. It is expected that the resultant PAI (pedometer step counts x RPE) will provide a more accurate measure of both volume and intensity of walking exercise. The index will in turn provide a more robust assessment of the total activity load that determines kcal expenditure during walking.

1.5 RATINGS OF PERCEIVED EXERTION

The purpose of this investigation was to develop and validate a PAI to measure total activity load (i.e. pedometer step counts x RPE) and estimate kcal expenditure during submaximal walking exercise. The development and validation of this model will allow individuals to better estimate kcal expenditure during submaximal walking exercise without the use of expensive laboratory equipment. From preliminary research, this index score has been shown to have a positive relation with kcal expenditure (r = 0.69) during selected walking and running treadmill speeds (Weary et al., 2006).

To assess the exercise intensity component of the PAI, we proposed using RPE. A RPE is a valid and easily obtained perceptual measure of relative exercise intensity (Robertson, 2005). It has been demonstrated that a RPE derived from a pictorial-verbal category metric, such as the OMNI Walk/Run scale, provides an estimate of the relative intensity of a specified locomotor activity. The OMNI Walk/Run Scale contains rating categories from 0 to 10 (Appendix D). A zero (0) indicates no exertion at all, whereas a ten (10) indicates maximal exertion during a given type of exercise. This category scale was employed in the present investigation to measure the perceptual intensity component of the PAI.

1.6 SENSEWEAR PRO ARMBAND™

As a secondary aim, it was expected that the kcal expenditure predicted from the PAI would correlate with the kcal expenditure determined by a commercially available product called the SenseWear Pro Armband™. The SenseWear Pro Armband™ is a motion sensor (accelerometer) that detects acceleration and deceleration in one or more directions of movement. Because acceleration increases in several dimensions with faster body movements, it was theorized that accelerometers should accurately determine kcal expenditure across a wide range of exercise intensities. The Armband has been found to accurately estimate kcal expenditure when exercise-specific algorithms are used (Jakicic et al., 2004). However, this tool is comparatively expensive and requires time consuming compliance regarding application and data monitoring (Van Coevering et al., 2005). Since the PAI is inexpensive and easy to use, it was compared to the Armband to determine comparative advantages in its application.

1.7 RESEARCH AIMS AND HYPOTHESES

This investigation developed a Physical Activity Index (PAI) that was calculated as the product of pedometer step count and RPE. The derived PAI was incorporated into a statistical model to predict kcal expenditure for a range of walking intensities. It was expected that the total activity load (i.e. pedometer step count x RPE) would provide an accurate estimate of energy expenditure during walking activities that vary in speed (i.e. intensity). The primary criterion measure to validate the PAI and develop associated kcal prediction models was oxygen consumption (VO_2)

as determined by indirect calorimetry. In addition, after concurrent validation was established, the estimated kcal expenditure of the PAI was compared to the measured kcal expenditure of the SenseWear Pro Armband™.

1.7.1 Research Aims

1. To determine the validity of the Physical Activity Index (PAI) as a measure of total activity load (i.e. volume of exercise x intensity of exercise) during treadmill walking using oxygen consumption (VO_2) and heart rate (HR) as criterion variables.
2. To develop and validate a statistical model that uses PAI scores to predict walking kcal expenditure derived from indirect calorimetry.
3. To compare kcal expenditure estimated by the PAI with that estimated by the SenseWear Pro Armband™.

1.7.2 Research Hypotheses

1. It was hypothesized that the PAI would evidence a strong positive correlation with VO_2 and HR during three different walking intensities, thus establishing concurrent measurement validity.
2. It was hypothesized that a statistical model using PAI as a predictor variable would explain significant variance in kcal expenditure as determined by indirect calorimetry during treadmill walking at varying intensities.

3. It was hypothesized that there would be a significant positive correlation between kcal expenditure values estimated by the PAI model and the SenseWear Pro Armband™.

2.0 LITERATURE REVIEW

The purpose of this investigation was to develop and validate a Physical Activity Index (PAI) to measure total activity load and estimate kcal expenditure during submaximal walking at varying intensities.

2.1 PHYSICAL ACTIVITY

Physical activity for improved health and well-being has been an important theme throughout much of western history (CDC, 2006). Public health recommendations have evolved from emphasizing vigorous activity for cardiorespiratory fitness to including more moderate levels of activity to address numerous health benefits. Experts agree that for improved health and well-being, individuals should perform physical activity at least 30 minutes on most, if not all, days of the week (CDC, 2006). It is also acknowledged that for most individuals, greater health benefits can be obtained by engaging in physical activity of more vigorous intensity or of longer duration (CDC, 2006).

2.2 BENEFITS OF PHYSICAL ACTIVITY

Physical activity has numerous beneficial physiological effects. Most widely appreciated are its influences on the cardiovascular and musculoskeletal systems, but benefits on the metabolic, endocrine, and immune systems are also considerable. Higher levels of regular physical activity are associated with lower mortality rates for both older and younger adults. Those who are at least moderately active on a regular basis have lower mortality rates than those who are less active (CDC, 2006). Physical activity has been shown to reduce the risk of the following diseases and/or conditions: cardiovascular disease, cancer, non-insulin-dependent diabetes mellitus, osteoarthritis, osteoporosis, and obesity.

2.3 EFFECTS OF PHYSICAL INACTIVITY

Low levels of physical activity are a major risk factor for morbidity and mortality from all causes (AIHW, 2006). According to the World Heart Federation, physical inactivity increases the risk of hypertension by 30 percent and coronary heart disease by 22 percent (WHF, 2002). It has also been shown that the relative risk of coronary heart disease associated with physical inactivity ranges from 1.5 to 2.4. This is an increase in risk comparable to that observed for high blood cholesterol, high blood pressure, or cigarette smoking (JAMA, 1995). Furthermore, physical inactivity is a significant contributor to overweight and obesity (WHO, 2002) and is associated with conditions and diseases such as: aneurysms, angina, atherosclerosis, back pain, heart attack, hemorrhoids, hypertension, hypercholesterolemia, osteoarthritis, osteoporosis, and type II diabetes.

2.4 PHYSICAL ACTIVITY RECOMMENDATIONS

Over the last three decades, the American College of Sports Medicine (ACSM) has recommended physical activity and exercise guidelines. While these guidelines have changed dramatically over the years, and while other groups have offered alternatives, the ACSM recommendations still remain the core for physical activity programming.

In 1978, the ACSM recommended that individuals exercise three to five days a week for 15 to 60 minutes, with an overall goal of expending 300 kcal per activity session. The next update of these guidelines occurred in 1990. ACSM retained the aerobic component of its original guidelines but added a strength training recommendation and underscored the importance of realistic, personalized exercise programming. The most recent ACSM recommendations for physical activity were published in 2006 in conjunction with the Centers for Disease Control and Prevention (CDC). At this time, several modifications were made to existing components of the ACSM guidelines. The aerobic component was increased to a minimum of 30 minutes of moderate intensity physical activity on most days of the week. Additionally, ACSM recognized that physical activity has an additive effect, and suggested that three 10-minute bouts of physical activity could provide health benefits similar to that obtained with one 30-minute session.

Currently, the 2006 ACSM guidelines remain in use. However, these physical activity guidelines are not uniformly agreed upon due to the introduction of recommendations from other well-regarded scientific groups. For example, the Institute of Medicine (IOM) recommends 60 minutes of moderate intensity physical activity each day. In addition, the President's Council on Physical Fitness and Sports (PCPFS) recommends 20 minutes of vigorous activity at least three times per week, whereas the American Heart Association recommends 30-60 minutes of physical activity five to seven days per week. These competing recommendations have created a debate as to which guidelines should be adopted for public health initiatives.

Regardless of the recommendation to be used, the health benefits of regular physical activity are well established (Welk & Blair, 2001; FITNESSGRAM®). In 1996, The Surgeon General of the United States issued a report titled "*Physical Activity and Health*" that summarized the contemporary consensus regarding the health benefits of physical activity (U.S. Department of Health and Human Services, 1996). The general conclusions from the report are listed below:

- *People of all ages, both male and female, benefit from regular physical activity.*
- *Significant health benefits can be obtained by including a moderate amount of physical activity (e.g., 30 minutes of brisk walking or raking leaves, 15 minutes of running, or 45 minutes of playing volleyball) on most, if not all, days of the week. Through a modest increase in daily activity, most Americans can improve their health and quality of life.*
- *Additional health benefits can be gained through greater amounts of physical activity. People who can maintain a regular regimen of activity that is of [comparatively] longer duration or of more vigorous intensity are likely to derive greater health benefits.*
- *Physical activity reduces the risk of premature mortality in general, and of coronary heart disease, hypertension, colon cancer, and diabetes mellitus in particular. Physical activity also improves mental health and is important for the health of muscles, bones, and joints.*
- *More than 60 percent of American adults are not regularly physically active. In fact, 25 percent of all adults are not active at all.*

- *Nearly half of American youths 12-21 years of age are not vigorously active on a regular basis. Moreover, physical activity declines dramatically during adolescence.*
- *Daily enrollment in physical education classes has declined among high school students from 42 percent in 1991 to 25 percent in 1995.*
- *Research on understanding and promoting physical activity is at an early stage, but some interventions to promote physical activity through schools, worksites, and health care settings have been evaluated and found to be successful.*

These statements highlight the importance of physical activity for health. However, many American adults do not get the recommended amount of daily physical activity, despite its proven benefits. In fact, more than 60% of American adults do not attain adequate physical activity to provide health benefits (CDC, 2003). Moreover, 40% of adults are not physically active at all in their leisure time (ACSM, 2006). Physical inactivity is more prevalent among women than men, among blacks and Hispanics than whites, among older than younger adults, and among the less affluent than the more affluent. The statistical prevalence of inactivity also indicates that major public health efforts are needed to promote physical activity in the American population. This has led to the Healthy People 2010 national health objectives to combat two of the leading United States health indicators: 1) physical inactivity and 2) overweight and obesity. These health indicators, along with eight others, are being used to measure the health of the nation from the year 2000 to 2010. As a group, the leading health indicators reflect the major health concerns in the United States at the beginning of the 21st century (Healthy People 2010, May, 2006).

Among the Healthy People 2010 national health objectives, physical activity is listed as the number one leading health indicator. Thus, public health goals have been developed to improve levels of physical activity among adults, adolescents, and children to reduce sedentary behavior. According to the 1997 National Health Interview Survey (NHIS), only 15% of American adults aged 18 years and older engaged in moderate physical activity for at least 30 minutes 5 or more days per week. A goal of Healthy People 2010 is to increase the proportion of adults who engage in regular, preferably daily, moderate physical activity for 30 minutes per day from 15% to 30% of the United States population. Another goal of Healthy People 2010 is to reduce the proportion of adults who do not engage in leisure-time physical activity from 40% to 20% of the United States population and to increase the proportion of adults who engage in vigorous physical activity (>20 min, three days per week) from 23% to 30% of the United States population.

In addition to the Healthy People 2010 initiatives, a recommendation originating in Tokyo, Japan, and adopted by United States public health agencies, involves accumulating 10,000 steps per day. The daily step count is typically recorded by a pedometer. This recommendation of 10,000 steps per day has become a popular means to both monitor and promote physical activity. Instead of engaging in physical activity for a specific duration (i.e. 30 min/day), this recommendation encourages individuals to walk 10,000 steps per day. For an adult, approximately 1,800-2,200 steps equals one mile. It has been found that on average, American adults walk approximately 4,000 – 6,000 steps a day (2-3 miles/day). Thus Americans must, on average, walk an additional 4,000 steps (approximately 2 miles) each day to reach the 10,000 step goal. At a brisk pace, 4,000 steps could be achieved in approximately 30 minutes. This duration is equivalent to the physical activity level recommended by the Centers for Disease

Control and Prevention and the American College of Sports Medicine. The use of pedometers to record the number of steps accumulated in a specified time period serves as a principal focus of the present investigation.

2.5 OVERWEIGHT AND OBESITY EPIDEMIC

Physical inactivity and poor dietary choices have, in part, been associated with the recent increase in overweight and obesity in the American population. In the past 20 years, the average body weight of Americans has increased dramatically. After adjusting for age and height, mean body weights have increased by nearly 10% in the past two decades, and the prevalence of clinical obesity has approximately doubled (Jeffery & Utter, 2003). It is currently estimated that greater than 66 percent of adults in the United States are overweight (BMI $\geq$ 25 kg/m^2) and greater than 33 percent of adults are classified as obese (BMI $\geq$ 30kg/m^2) (CDC, 2004). Although not all segments of the population have experienced the same degree of increase in body weight, the obesity epidemic is affecting the entire United States population regardless of age, geographic region, social economic status, or ethnicity. The speed and magnitude of this epidemic are unprecedented and have signaled a need for a national public health agenda (Jeffery and Utter, 2003).

It is widely agreed that although there is individual (genetic) variability in susceptibility to obesity, the rapid increase in obesity among the United States population cannot be due to DNA determinants alone. In fact, changes in body weight have been shown to be caused by changes in behaviors that effect kilocalorie (kcal) intake and those that effect kcal expenditure. Many researchers believe that these behaviors are largely affected by the environment and evolving technology. For example, it has been shown that the 147% increase in fast food restaurants from 1972 to 1995 in the United States was associated with a significant increase in daily kcal intake (Harnack et al., 2000). In addition to more fast food restaurants, it was found that Americans eat at restaurants with greater frequency and the portion sizes are significantly larger as compared to 1972 levels. Both of these lifestyle factors potentially exacerbate the obesity epidemic (Harnack et al., 2000). Taken together, it is possible that the increase in fast food restaurants, portion sizes, and frequency of eating at restaurants could have contributed significantly to the increase in overweight and obesity during the past two decades.

In addition to the changing environment, technology is also thought to contribute to the obesity epidemic in the United States. For example, there has been a consistent trend in the last 20 years for use of private automobiles to commute to work, school, and leisure destinations. This increase in the use of private automobiles has led to a decrease in modes of transportation such as walking and biking. Furthermore, researchers have suggested that the participation in inactive entertainment such as television viewing and home computer use has also contributed to the obesity epidemic. For example, *Nielson Media Research* found that during the past three decades, the percentage of homes with multiple televisions increased from 35% in 1970 to 75% in 2000. In addition, *Nielsen* data estimated that persons over 12 years of age viewed television an average of 28 hours per week as compared to an estimate of 10.4 hours per week from a time use study of Americans conducted in 1965 (French et al., 2001). These technological advances, along with several others, have made it convenient for the American population to replace physical activity with sedentary pursuits. Combined, the changing environment and technology have played a significant role in the increase in overweight and obesity in the United States.

2.6 RISKS ASSOCIATED WITH OBESITY

Research indicates that excess amounts of body weight can contribute to health complications that increase mortality. It is estimated that overweight and obesity contribute to approximately 325,000 deaths per year (Allison et al., 1999). In addition, obesity increases the risk of various chronic diseases such as heart disease and diabetes (Rimm et al., 1995; Wing et al., 1999), and is an independent risk factor for hypertension, hyperlipidemia and insulin resistance. Furthermore, overweight and obesity is associated with disability, decreased health-related quality of life and increased health care use, all of which translate into increased health care costs to the American public (Jackson, 2002). Obesity has also been linked to other serious health problems such as musculoskeletal disorders and cancer (Tsai et al., 2005). Since obesity is a demonstrated health risk factor for both men and women, interventions are needed to prevent and/or reduce the prevalence of this risk factor. In this regard, Leon (1987) suggests that obesity is a risk factor that is easier to avoid than to treat. Therefore, body fat weight gain should be monitored and controlled before it develops into unmanageable obesity.

One way of controlling or preventing body fat gain is through exercise intervention. Exercise training programs have been effective in reducing percent body fat because they increase the individual's kcal output above previously sedentary levels (Ross et al., 2004).

2.7 BEHAVIORAL WEIGHT LOSS INTERVENTIONS

Although physical activity has positive effects on several physiological factors, this section of the literature review will focus on the effect of physical activity on weight loss interventions.

Weight loss programs that include physical activity are particularly important because not only do they help prevent weight gain, but they also help to prevent several underlying risk factors associated with obesity.

In all weight loss programs, an energy deficit must be attained to lose weight. This energy deficit can be accomplished by either decreasing dietary kcal intake and/or by increasing exercise related kcal expenditure (Wing, 2001). This section of the literature review will focus on weight loss mechanisms specific to kcal expenditure via physical activity.

Williamson and colleagues (1993) examined the association between physical activity level and the 10-year change in body weight in 3,515 men and 5,810 women aged 25-74 years. At baseline and 10-year follow-up, participants indicated whether their level of recreational and non-recreational physical activity was of low, moderate, or high intensity. Participants' weights were measured at baseline and follow-up. The investigators found no relation between baseline activity levels and subsequent weight change in men or women. However, men whose activity levels were low at baseline and remained low at follow-up, and those with decreases in activity level from baseline to follow-up, gained 1.3 kg and 1.4 kg more, respectively, than men whose activity levels were high at both assessments. Women whose activity was low at both measurement periods, and those with decreases in activity from baseline to follow-up, gained 2.1 kg and 1.9 kg more, respectively, than women whose activity levels were high at both measurements. The relative risk of major weight gain (>13 kg) for people whose activity level was low at both the baseline and follow-up interviews was 2.3 times higher in men and 7.1 times higher in women than in individuals whose activity level was high at baseline and follow-up. These results suggest that individuals who maintain consistently high levels of physical activity experience less weight gain than people who do not exercise regularly.

French and colleagues (1994) examined predictors of weight change over a 2-year period in 1,639 male and 1,913 female employees from area worksites. Body weight was measured at baseline and 2-year follow-up. Physical activity was measured with a 13-item exercise frequency recall. Participants indicated how often they participated in leisure-time and occupational physical activities of varying intensity. The average weekly frequency of physical activity was calculated for each of four categories: (1) high-intensity activities; (2) moderate-intensity activities; (3) group and racquet sports; and (4) occupational activity. Increases in physical activity from baseline to follow-up were associated with weight loss. Among women, an increase of one walking session per week was associated with a decrease in body weight of 0.79 kg, and an increase of one high-intensity exercise training session per week was associated with a decrease in body weight of 0.63 kg, over a 2-year period. For men, an increase of one walking session per week or one high-intensity activity was associated with a decrease of 0.39 or 1.59 kg, respectively, over the 2-year period.

DiPietro and colleagues (1997) followed 4,599 men and 724 women who were evaluated at the Cooper Clinic in Dallas, Texas, during the time between 1970 and 1994. This study assessed body weight and physical activity at three time points. The changes in fitness from the first to the second examination were used as a predictor of weight gain by the third examination. At each examination, weight, cardiorespiratory fitness, and other clinical variables were measured. The interval between the first and second examinations averaged 1.8 years, and the total observation period from the first to the third examination was about 7.5 years. Results showed that each 1-minute improvement in treadmill time from the first to the second examination was associated with a 9% decrease in the odds of a 5 kg weight gain for women and a 14% decrease for men. There was an even stronger reduction in the odds (21%) of a 10 kg weight gain in both women and men with each additional minute of performance on the treadmill test. The authors concluded that a physically active lifestyle may prevent weight gain later in life (DiPietro, 1997).

In addition to its effects on weight loss, physical activity appears to be crucial for maintaining weight loss. One study examined self-reported activity levels of obese women who regained weight after successful weight loss ("relapsers"), formerly obese women who maintained their weight loss ("maintainers"), and normal-weight women who maintained their weight (controls) (Kayman, Bruvold, & Stern, 1990). Regular physical activity (at least 30 minutes, 3 days/week) was reported by 90% of the maintainers and 82% of the controls, but by only 34% of the relapsers. These results suggest the importance of physical activity in maintaining weight, both among normal-weight individuals and formerly obese individuals who have lost weight.

The National Weight Control Registry identified a group of 1,047 women and men who lost at least 30 pounds of total body mass (13.6 kg) and maintained that loss for at least 1 year. The average weight loss in this group was 64 pounds (29.0 kg) over an average of 6.9 years. Those successful in maintaining weight averaged 1 hour or more of moderate to vigorous intensity physical activity per day. Similarly, Schoeller et al. (1986), using doubly-labeled water to determine energy expenditure, found high levels of physical activity among those successful in maintaining weight loss. The maintainers had an average daily energy expenditure of 1.9 metabolic equivalent tasks (METs), which requires about 80 minutes of moderate intensity physical activity or 35 minutes of vigorous activity per day.

Although the immediate effects of physical activity on weight reduction are limited, the long-term cumulative effect of small changes in activity level can be very beneficial. For example, if a 100 pound person played golf only 2 hours per outing (an additional 350 kcal per outing), for 2 days a week (700 kcal), it would take about 5 weeks, or 10 golfing days, to lose 0.45 kg (1 pound) of fat (3,500 kcal). If the person played golf year-round, golfing 2 days per week would hypothetically produce a 4.5 kg loss of fat during the year, provided that dietary kcal intake remained fairly constant (Katch & McArdle, 1993).

It is speculated, based on the epidemiological studies reviewed above, that an individual who is regularly active throughout his or her lifetime would be approximately 13.6 kg (30 pounds) lighter by age 65 than someone who led a consistently sedentary lifestyle over this period. Jeffery and French (1997) found that sedentary men and women 20-45 years of age gained an average of 0.86 and 0.64 kg, respectively, each year compared to their active counterparts. Physical activity then, may play a very important role in long-term body weight regulation.

2.8 PEDOMETERS

The accurate measurement of free-living physical activity is essential for research studies in which physical activity is an outcome variable. According to Freedson (2005), "Physical activity surveillance and observational studies of the association between physical activity and health outcomes require a robust activity measure to establish accurate estimates of the dose of activity needed for specific outcomes" (Freedson, 2005). In addition, physical activity interventions require an accurate measure of activity dosage in order to establish dose-response relations that explain intervention effectiveness. Such accurate assessments of physical activity are necessary if the physiologic mechanisms linking physical activity and health are to be completely understood (Freedson, 2005).

Due to the public health input in developing physical activity recommendations, physical activity monitors have become increasingly popular. It is recognized that the most common form of physical activity assessment uses self-reported recall questionnaires. However, there are limitations regarding the individuals' ability to accurately recall all physical activity performed over a specified period of time. Thus, physical activity monitors, such as pedometers, are now being used to objectively measure physical activity.

Pedometers are inexpensive, light-weight, and unobtrusive tools that measure physical activity by responding to vertical accelerations of the hip during gait cycles (Schneider, 2004). Pedometers typically include a horizontal, spring suspended lever arm that moves up and down with normal ambulation (i.e. walking or running). An electrical circuit closes with each movement detected and an accumulated step count is displayed digitally on a feedback screen. Pedometers do not, however, record velocity or intensity of movement, restricting their use to measure total accumulated steps/day and associated kcal expenditure (President's Challenge Report, 2006).

According to manufacturers' recommendations, pedometers should be worn on a waistband or placed horizontally in a pocket midway between the umbilicus and the hip. Most pedometer models provide data on the quantity of steps taken, distance traveled, and estimated energy expended. Typically, the pedometer user must manually enter a number of variables including gender, stride length, weight, and/or age in order to derive estimated kcal expenditure from accumulated step counts.

Pedometers have been found to capture changes in lifestyle ambulatory behaviors that are not typically considered exercise, but in fact help to increase energy expenditure. Significant improvements have been noted in weight management, insulin sensitivity, blood pressure, and lipid profiles, as a result of participation in physical activity interventions using pedometers as motivational tools (Tudor-Locke et al., 2002; Talbot et al., 2003; Moreau et al., 2001). Although most research to date has involved physical activity assessment, pedometers may also serve to motivate increased activity levels by increasing cognitive awareness (U.S. Dept. of Health and Human Services, 1996) and self efficacy (Tudor-Locke et al., 2002). For example, a pedometer can be used as a tracking device, a feedback tool, and as an environmental cue for physical activity participation. Used in combination with written physical activity tracking logs, pedometers have been found to be an effective way to increase daily physical activity (Tudor-Locke, Myers, & Rodger, 2001).

For example, Croteau (2003) examined the effects of an 8-week, pedometer-based intervention on lifestyle activity. Participants were 37 college employees who volunteered to participate in the study. The intervention consisted of goal setting, pedometer use, self-monitoring, and weekly e-mail reminders. Physical activity measures (pedometer, survey) were taken at baseline and immediately following the intervention. Results indicated a significant increase in average daily steps from 8,565 (SD $\pm$ 3121) steps at baseline to 10,538 (SD $\pm$ 3,681) steps at the end of the program. This study indicates that a pedometer-based lifestyle intervention is effective in increasing the daily physical activity of adults.

Furthermore, Speck and Looney (2001) examined the effect of a minimal intervention (daily records of physical activity) on activity levels in a community sample of working women. Using a longitudinal, pretest-posttest design, 49 working women were randomly assigned to the control (n = 25) or intervention group (n = 24). At pretest and posttest, subjects completed self-report questionnaires that measured psychological, social-environmental, physical activity, and demographic variables. Subjects in the intervention group kept daily records of their activities during the 12-week study, while those in the control group kept no records. In order to compare activity in the two groups, all subjects wore pedometers that recorded number of steps taken daily. The control subjects were blinded to the digital display of their daily step count. In contrast, the intervention group was informed of their daily step counts. Results indicated that the step count was significantly higher in the intervention than control group (2,147 $\pm$ 636 steps). It was concluded that pedometer step count monitoring is a cost-effective and acceptable intervention that may increase activity levels in women.

Pedometers have been found to be a valid method for assessing ambulatory modes of physical activity such as walking and climbing stairs (Tudor-Locke et al., 2002). In a systematic review of twenty five published articles, Tudor-Locke and colleagues (2002) compared pedometers to other methods of physical activity monitoring and found a high correlation between pedometers and accelerometers (r = 0.86), physical activity observation (r = 0.82), energy expenditure (r = 0.68), and self report questionnaires (r = 0.33).

Studies have shown that pedometers are most accurate at measuring steps taken (Bassett et al, 1996; Hendelman, Miller, Baggett, Debold, and Freedson, 2000), less accurate at estimating distance traveled (Bassett et al., 1996; Hendelman et al., 2000) and even less accurate at estimating energy expenditure (Bassett et al., 2000). For these reasons, researchers have recommended that steps taken, or steps/day, be universally adopted as a standard unit of measurement for collecting, reporting, and interpreting pedometer data (Rowlands et al., 1997; Tudor-Locke & Myers, 2001).

Studies have also indicated that walking speed may have an effect on the accuracy of pedometer counts, distance covered, and kcal expenditure. Crouter et al. found that pedometers were less accurate at slower speeds (54 m/min) than at faster speeds (80 m/min) due to the less pronounced vertical accelerations of the waist at slow walking speeds (Crouter, 2003). It was also found that pedometers tend to overestimate distance traveled at slower speeds and underestimate distance traveled at faster speeds, with 80 m/min being the most accurate speed for most pedometers (Crouter et al., 2003). Furthermore, Crouter suggests that electronic pedometers underestimate kcal expenditure during lifestyle activity (i.e. gardening, housework) (Crouter et al., 2003).

Advances in technology and quality control have led to improvements in the reliability and validity of pedometers. In a recent review of five contemporary electronic pedometers, Bassett et al. (1996) reported acceptable results for most of the monitors, with exceptional reliability and validity exhibited by the Yamax Digi-Walker (Yamax Inc., Tokyo, Japan). The Digi-Walker model provided the most accurate assessment of step counts and distance walked for each of the walking paces tested. In a field-based evaluation using a 4.88 km sidewalk, the Digi-Walker measured the number of steps and distance traveled within 1% of actual values (Bassett et al., 1996). In addition, Schneider et al. (2004) compared 13 models of pedometers, finding the Yamax Digi-Walker to be superior. Based on the results regarding the models examined by Bassett et al. (2004), the criterion pedometer selected for the present investigation will be the Yamax Digi-Walker SW-200. Overall, the Yamax SW series pedometers have consistently been shown to be among the most accurate pedometers available on the commercial market (Bassett, 2002). Specifically, the Yamax SW-701 was the only pedometer out of the 13 pedometers tested by Schneider et al. whose step count measure did not differ significantly from the actual steps taken (Schneider et al., 2004). Schneider concluded that of the 13 pedometers tested, 4 pedometers seemed to be suitable for applied physical activity research: Kenz Lifecorder, Yamax 200, New-Lifestyles-2000, and Yamax 701 (Schneider et al., 2004).

Because of these findings, several investigators have recently compared the Yamax Digi-Walker to other, more established assessments of physical activity to examine convergent validity of the unit (Welk, 2000). Eston and colleagues (1998) reported correlations of 0.92 between step counts and a scaled VO_2 measure during unstructured, low-intensity activity in children. For adult subjects, Differding et al. (1998), observed average correlations of r = 0.76 between the Tritrac and the Yamax Digi-Walker pedometers across 7 days of monitoring. These two studies provide preliminary evidence for the validity of the Digi-Walker step counter as an objective indicator of habitual physical activity (Welk et al., 2000). Since the Yamax pedometers have been examined in controlled experimental settings and have been found to be valid and reliable through test, re-test reliability studies (Welk et al., 2000), the Yamax SW-701 pedometer was chosen for the present study. In the present investigation, the Yamax SW-701 Digi-Walker was chosen over the criterion pedometer (Yamax SW-200) used in Schneider's study because it provides additional information regarding estimated kcal expenditure and distance traveled.

The National Institutes of Health recommends the use of pedometers as a means to achieve 10,000 steps a day for optimal health. However, while pedometers accurately measure motion of the hip flexor, they do not accurately measure exercise intensity and associated kcal expenditure. For example, it is known that an individual who walks 500 steps on a 5% grade will use more kcal than an individual who walks 500 steps on a 0% incline. In addition, it is also known that an individual who runs 500 steps will use more kcal than an individual who walks 500 steps. So although pedometers can be useful tools, they do not account for the differences in intensity of exercise, and thus do not accurately measure kcal expenditure. Because pedometers do not account for intra- and inter-individual differences in exercise intensity, it is proposed that an adaptation to the pedometer step count system is needed to account for this methodological limitation. As such, we propose to compliment pedometer step counts with RPE to provide a more accurate measure of exercise intensity and associated kcal expenditure.

2.9 RATINGS OF PERCEIVED EXERTION

Ratings of perceived exertion (RPE) are indicators of the physical strain and associated subjective fatigue and discomfort experienced during dynamic and resistance exercise. They provide a quantitative measure to assess exertional tolerance, prescribe physical activity intensity, and track exercise conditioning outcomes (Robertson, 2004; Welk, 2002; Noble, 1996). The concept of and methods to measure exertional perceptions were developed and validated by Gunnar Borg, a Swedish experimental psychologist (Noble, 1996; Borg, 1998). Borg's work in the late 1950's and early 1960's demonstrated a consistent positive relation between heart rate, oxygen consumption and RPE during load incremented protocols involving various modes of aerobic exercise. This perceptual-physiological congruence formed the conceptual basis of "Borg's Effort Continua Model".

2.9.1 Borg's Effort Continua Model

The Effort Model proposes that the responses to exercise follow along inter-related physiological, perceptual, and performance continua. The relation between the physiological demands of exercise performance and the perception of exertion associated with the exercise performance forms a functional linkage that serves as the rationale for Borg's Effort Continua Model. As intensity of the exercise performance increases, there is a corresponding and inter-dependent change in both the perceptual and physiological responses (Borg, 1998; Noble, 1996; Robertson, 2004). In this context, an RPE provides much of the same information regarding exercise tolerance, intensity self-regulation and activity preference as do traditional physiological responses (i.e. heart rate and oxygen consumption). It is important to note that the validation of the perceptual-physiological link described by the Effort Continua Model is essential for the application of ratings of perceived exertion in sport, clinical, and public health settings.

2.9.2 Physiological Mediators of Perceived Exertion

There are three classes of perceptual signals associated with physiological mediators: respiratory-metabolic, peripheral, and non-specific (See Table 2.1). Respiratory-metabolic mediators include aerobic metabolic, and in particular, ventilatory drive during exercise. Peripheral mediators are localized in the limbs and the trunk and involve alterations in energy production and contractile properties of skeletal muscle. Non-specific mediators include general or systemic physiological responses associated with exercise (Table 2.1) (Robertson, 2004).

Table 2.1. Physiological Mediators of Perceived Exertion

Respiratory-Metabolic	**Peripheral**	**Non-Specific**
Pulmonary Ventilation	Metabolic Acidosis (pH, Lactic Acid)	Hormonal Regulation (catecholamines, β-endorphins)
Oxygen Uptake	Blood Glucose	Temperature Regulation (core and skin)
CarbonDioxide Production	Blood Flow to Muscle	Pain
Heart Rate	Muscle Fiber Type	Cortisol and Serotonin
Blood Pressure	Free Fatty Acids	Cerebral Blood Flow and Oxygen
	Muscle Glycogen	

Robertson RJ. Perceived Exertion for Practitioners: Rating Effort with the OMNI Picture System. Champaign, IL: Human Kinetics. 2004

One of the proposed physiological mediators of the respiratory-metabolic perceptual signal of exertion is total body oxygen uptake measured in absolute (i.e. L/min) and relative (i.e. $\%VO_{2max}$) units. As previously mentioned in conjunction with Borg's Effort Continua Model, there is a functional link between the physiological demands of exercise and perceptual signals of exertional intensity. The perceptual signals associated with oxygen uptake, are in part mediated through ventilatory drive required to support aerobic metabolism (Robertson, 2004). As the ventilatory drive increases in response to greater aerobic energy requirements, the increase in developed inspiratory muscle tension is consciously perceived as a signal of respiratory-metabolic exertion (Robertson, 2004; Noble, 1996). During dynamic exercise, the correlation between VO_2 and RPE ranges from r = 0.76 to r = 0.97 (Robertson, 2004; Noble, 1996).

The increase in VO_2 yields a corresponding and parallel increase in RPE. Low intensity exercise results in a lower VO_2 with RPEs in the lower response zone (OMNI-RPE = 1 to 3). High intensity exercise results in a higher VO_2 with RPEs in the higher response zone (OMNI-RPE = 7/8 to 10). Numerous reports established that RPE and VO_2 have a parallel and interdependent correspondence during dynamic exercise (Robertson, 2006). Because kcal expenditure can be calculated from $VO_{2,}$ we propose that by using RPE as a measure of relative exercise intensity, it is possible to develop a comparatively more accurate estimate of kcal expenditure for walking exercise. Such a psychophysiological mechanism will more precisely link measured physical activity with estimations of kcal expenditure.

Because pedometers do not accurately measure kcal expenditure, one of the purposes of this study is to develop and validate the PAI. The PAI combines pedometer step count and RPE, the latter measure taken as an indication of the relative exercise intensity. The proposed PAI calculates a total activity load (i.e. pedometer step count x RPE) that will be used to develop a model to predict kcal expenditure during varying intensities of walking exercise.

Lee et al. (2003) reported that the beneficial health outcomes of physical activity were positively related to the relative intensity (i.e. percent of maximum) of the exercises that were performed. Normally, determination of the relative exercise intensity requires measurement of an individual's maximal oxygen consumption (VO_{2max}), a procedure not practical in field-based settings. RPE was chosen to serve as the measure of relative intensity in this current investigation because it has been shown to linearly relate to VO_2 during most dynamic exercise modes (Noble & Robertson, 1996). In fact, perceptual signals associated with VO_2 are mediated by the ventilatory drive required to support aerobic metabolism (Noble & Robertson, 1996). Correlation coefficients for the relation between VO_2 and RPE range from r = 0.76 to r = 0.97 for both intermittent and continuous arm and leg exercise (Edwards et al., 1972). Furthermore, RPE is applicable over a wide range of clinical, recreational, and athletic settings (Noble & Robertson, 1996). Thus, RPE will serve as the relative intensity component of the PAI energy cost prediction model.

Borg's scales of perceived exertion have been validated for weight bearing and non-weight bearing aerobic exercise in a number of ambient environmental conditions (Robertson, 2004). They have also stimulated the design of new category RPE scales (Robertson, 2004). These new scales not only rely on verbal descriptors but also on pictorial descriptors to provide visual "cognitive text" for perceptual responses (Robertson, 2004). The majority of these pictorial-verbal metrics are known as the OMNI Scales, having various formats specific to children and adults. The OMNI Scales are valid for different modes of exercise such as walking/running, cycling, stepping, and resistance exercise. Each one of these scales has undergone experimental validation using the same, or similar, physiological correlates that Borg used in developing the original RPE scales (Robertson, 2004). Concurrent validity coefficients for the interrelations between OMNI Scale RPE and both VO_2 and HR during walk-run exercise range from r = 0.67 to r = 0.88 for both males and females (Utter et al., 2004).

2.9.3 Undifferentiated/Differentiated RPE

RPE measurements can be undifferentiated for the overall body (RPE-O) or they can be anatomically differentiated to specific body regions (i.e. RPE-Leg and RPE-Chest). The differentiated RPE distinguishes between anatomically regionalized perceptual signals, whereas the undifferentiated RPE serves as a global indicator of general exertion and often approximates the mathematical average of the differentiated RPE values (Robertson, 2004; Noble, 1996).

Because the undifferentiated perceptual signal for the overall body is an integration of aerobic metabolic inputs from various body regions, it will be used in the present investigation, presenting as a robust measure to determine relative walking intensity and predict associated kcal expenditure.

2.10 RPE AS A PREDICTOR FOR VO_2, ENERGY COST, AND PERFORMANCE

RPE can be used as the principle measurement during both laboratory and field-based tests to estimate aerobic fitness and energy cost. One such test that can be used to predict VO_{2max} is the RPE run test (Robertson, 2004). The RPE run test is a submaximal evaluation that can be easily administered as part of a daily training program to assess clients' progress and classify aerobic fitness (Borg 1998). During the RPE run test, subjects are asked to run a specific distance (i.e. 220-660 yds) at a slow, moderate, and fast pace. After completion of each of the run tests (slow, moderate, and fast), the amount of time required for the individual to complete the test and RPE are recorded. The evaluator then converts time taken to complete the test and distance covered into speed (mph). Next, a plot using RPE and speed (mph) is created to estimate aerobic fitness. Robertson has shown that the results of this plot correlate strongly with treadmill VO_{2max} ($r = 0.92$) (Robertson, 2004).

RPE can also be used to estimate energy expenditure during exercise. As an example, a chart created by Moyna et al. (2001) lists the length of time required to expend 200 kcal of energy for each of six exercises (treadmill, ski simulator, stair stepper, rower, rider, and cycle) according to three different RPE zones. The OMNI RPE zones used in this chart are 4, 5, and 7. As RPE increases, the time it takes to use 200 kcal decreases. For example, it takes 21 minutes for a female to use 200 kcal when walking on a treadmill at a target RPE of 4. If the same female walks on a treadmill at a target RPE of 7, it takes only 17 minutes for her to use 200 kcal.

In many settings, it is practical to use a prediction technique (model) to estimate a client's capacity for exercise performance (Noble & Robertson, 1996). This can be done rather easily with equations that use RPE responses to short-duration, low-intensity tests. Prediction models based on RPE can be used to estimate a client's VO_2, heart rate, peak power output, and endurance time (Robertson, 2004). Such models can be found in Table 4.4 of R. J. Robertson's book entitled, *Perceived Exertion for Practitioners: Rating Effort With the OMNI Picture System.* The tests that employ these prediction models are typically easy to administer and require very little time to complete (Robertson, 2004).

2.11 ACCELEROMETRY

A secondary purpose of this present investigation was to compare kcal expenditure estimated by the PAI with that estimated by an accelerometer. Portable devices such as accelerometers are used to estimate energy expenditure in physical activity intervention trials intended to decrease excess body weight. One such accelerometer is the SenseWear Pro Armband™ that calculates energy expenditure for a range of aerobic activities. The SenseWear Pro Armband™ is a non-invasive device that is worn on the right posterior triceps (Body Media, 2005). This accelerometer acquires physiological measures of heat dissipation-flux, galvanic skin response, skin and ambient temperature and also two axes acceleration-movement (Feo et al., 2005). The instrument takes into consideration gender, age, height, and weight of the subject and uses proprietary algorithms developed by the manufacturer to calculate estimated energy expenditure (Feo et al., 2005).

A study conducted by Jakicic et al. demonstrated the accuracy of the SenseWear Pro Armband™. Forty subjects performed four exercises (walking, cycling, stepping, and arm ergometry) with exercise lasting 20-30 min and intensity increasing at 10 min intervals. Subjects wore the SenseWear Pro Armband™ on the right arm, and energy expenditure (EE) was estimated using proprietary equations developed by the manufacturer. Estimated energy expenditure from the SenseWear Pro Armband™ was compared with energy expenditure determined form indirect open-circuit calorimetry, which served as the criterion measure. When a generalized proprietary algorithm was applied to the data, the SenseWear Pro Armband™ significantly underestimated total energy expenditure by (mean $\pm$ SD) 14.9 $\pm$ 17.5 kcal (6.9 $\pm$ 8.5%) during walking exercise, 32.4 $\pm$ 18.8 kcal (28.9 $\pm$ 13.5%) during cycle ergometry, 28.2 $\pm$ 20.3 kcal (17.7 $\pm$ 11.8%) during stepping exercise, and overestimated total energy expenditure by 21.7 $\pm$ 8.7 kcal (29.3 $\pm$ 13.8%) during arm ergometer exercise ($P \leq 0.001$). At the request of the investigators, exercise-specific algorithms were developed by the manufacturer and applied to the data. The newly formulated calculations resulted in non-significant differences in total energy expenditure between indirect calorimetry and the SenseWear Pro Armband™. Differences between indirect calorimetry and the SenseWear Pro Armband™ for the walk, cycle ergometer, step, and arm ergometer exercises were as follows: 4.6 $\pm$ 18.1 kcal (2.8 $\pm$ 9.4%), 0.3 $\pm$ 11.3 kcal (0.9 $\pm$ 10.7%), 2.5 $\pm$ 18.3 kcal (0.9 $\pm$ 11.9%), and 3.2 $\pm$ 8.1 kcal (3.8 $\pm$ 9.9%), respectively. Jakicic et al. concluded that when exercise-specific algorithms are used, the SenseWear Pro Armband™ provides an accurate estimate of energy expenditure when compared to indirect calorimetry for exercise of the types examined (Jakicic et al., 2004).

In another study, King et al. (2004) evaluated the validity of five physical activity monitors: the Computer and Science Application (CSA) Actigraph, TriTrac-R3D, RT3, SenseWear Pro Armband™, and BioTrainer-Pro. Ten healthy men and 11 healthy women performed 10 min of treadmill walking at 54, 80, and 107 m/min and treadmill running at 134, 161, 188, and 214 m/min. The CSA, TriTrac-R3D, RT3, and the BioTrainer-Pro accelerometers were placed side by side bilaterally at the waist in the axillary position and the SenseWear Pro Armband™ monitors were placed bilaterally on the posterior portion of each arm in the mid-humeral position. Simultaneous measurements of body motion and indirect calorimetry were continuously recorded during all exercise. There was no significant difference in the mean energy expenditure recorded bilaterally (i.e. placement of monitor on left hip/arm vs. right hip/arm) by any of the monitors ($p < 0.05$) at any treadmill speed. The SenseWear Pro Armband™, TriTrac-R3D, and RT3 recorded significantly higher increases in mean energy expenditure (EE) across all walking and running speeds ($p < 0.05$) as compared to EE measured via indirect calorimetry. Below the speed of 161 m/min, the mean EE recorded by the BioTrainer-Pro and the CSA increased significantly ($p < 0.001$) as compared to EE measured via indirect calorimetry. However, there was no significant difference ($p > 0.10$) in mean EE recorded by either monitor for speeds above 161 m/min as compared to EE measured via indirect calorimetry. In general, all monitors overestimated EE at most treadmill speeds when compared to indirect calorimetry ($p < 0.001$), except for the CSA, which underestimated EE at the lowest and highest speeds. King et al. (2004) concluded that the CSA provided the best estimate of total EE at walking and jogging speeds, the TriTrac-R3D provided the best estimate of total EE at running speeds, and the SenseWear Pro Armband™ provided the best estimate of total EE for the greatest number of walking and running speeds examined.

The methods to predict energy expenditure from accelerometer output have also undergone technological advancement in recent years. Crouter et al., (2005) examined 48 subjects performing various activities chosen to represent sedentary, light, moderate, and vigorous intensities. The purpose of the study was to develop a regression model that predicted energy expenditure from accelerometer counts for a wide range of physical activities. Eighteen activities were divided into three routines with each routine being performed by 20 individuals, for a total of 60 tests. Forty-five tests were randomly selected for the development of the new equation, and 15 tests were used to cross-validate the new equation and compare it against already existing equations. During each routine, the participant wore an Actigraph accelerometer on the hip, while oxygen consumption was simultaneously measured by a portable metabolic system. For each activity, the coefficient of variation (CV) for the accelerometer counts per 10 seconds was calculated to determine prediction models specific to walking/running or some form of lifestyle/leisure activity. If the CV was ≤ 10, then a walk/run regression equation was used, whereas if the CV was > 10, a lifestyle/leisure time physical activity regression was used. In the cross-validation group, the mean estimates using the new algorithm (2-regression model) were within 0.75 metabolic equivalents (METs) of measured METs for each of the activities performed ($p > 0.05$), which was a substantial improvement over the extant single-regression models (Crouter et al., 2005).

Although accelerometers, specifically the SenseWear Pro Armband™, generally provide valid and reliable measures of energy expenditure, the cost of these instruments is approximately $950 per unit (Body Media; year of costing 2007). This cost is prohibitive for most practical large-scale applications and their use requires technical expertise and additional hardware and software to calibrate, input, distil, and analyze data (Eston, 1998). Researchers are beginning to acknowledge that, in terms of practicality, pedometers currently offer a better choice for a low cost ($5 to 50 per unit; year of costing 2007), objective monitoring tool.

2.12 PHYSICAL ACTIVITY INDEX

The purpose of this study was to develop and validate a physical activity index (PAI) as a measure of total activity load (i.e. pedometer step count x RPE). Pedometer step counts and RPE were multiplied to create an index score. From preliminary research, this index score has been shown to have a strong positive relation with kcal expenditure (r = 0.69) during selected walking and running treadmill speeds (Weary et al., 2006).

More specifically, pilot data was collected on sixteen recreationally active male (n = 7) and female (n = 9) subjects to determine the relation between PAI and kcal expenditure measured via indirect calorimetry. All subjects performed an intermittent treadmill test consisting of the following 5 min counterbalanced exercise intensities: Level Walk (LW; 4.02 $km \cdot hr^{-1}$, 0% grade), Hill Walk (HW; 5.63 $km \cdot hr^{-1}$, 5% grade), and Run (R; 8.04 $km \cdot hr^{-1}$, 2.5% grade). Each bout was separated by five min of rest. During each of the three exercise bouts, VO_2, overall body RPE (RPE-O), pedometer step count, and kcal expenditure were measured. There was a significant difference ($p < .05$) between each exercise intensity for RPE, pedometer step count, and kcal expenditure indicating three distinct training volume zones. The PAI was then determined by multiplying the RPE-O by the corresponding pedometer step count for each exercise intensity. A paired sample correlation demonstrated a significant ($p < .05$) positive relationship (r = .69) between the PAI and kcal expenditure (Weary et al., 2006).

It was anticipated that the PAI would serve as an easy and inexpensive means to estimate kcal expenditure during walking exercise. Other tools, such as the SenseWear Pro Armband™ have been shown to be accurate measures of kcal expenditure (Jakicic, 2004), however, these instruments are comparatively expensive and require technical knowledge for computer-based data entry and interpretation. Thus, the PAI can serve as an inexpensive and easily applied public health tool which can assist the lay individual in estimating kcal expenditure during varying intensities of walking exercise.

3.0 METHODS

The primary purposes of this study were to examine the validity of the Physical Activity Index (PAI) as (a) a measure of total activity load (i.e. volume of exercise x intensity of exercise) and (b) as an estimate of total kcal expenditure during submaximal treadmill walking. A secondary purpose was to compare estimated kcal expenditure determined by the PAI model to the estimated kcal expenditure determined by the SenseWear Pro Armband™. All procedures were approved by the Institutional Review Board (IRB) at Slippery Rock University. Written informed consent was obtained from all participants prior to their participation in this study.

3.1 SUBJECTS

Thirty two recreationally active females ranging in age from 18 to 24 years participated in this study. Recreationally active individuals were those who performed aerobic and/or resistance training exercise for 30-60 min on 2-3 days/week, but who did not participate in collegiate or professional sport. At the time of recruitment and prior to exercise testing, potential subjects were eliminated from participation owing to pre-existing conditions that would place them in the "high risk" stratification for non-physician supervised exercise testing according to the American College of Sports Medicine (Appendix A). Descriptive statistics are shown in Table 3.1.

3.2 SUBJECT CHARACTERISTICS

Descriptive data for physical and physiological variables were calculated as mean $\pm$ SD using SPSS 14.0 for Windows (Chicago, IL) (Table 3.1). Thirty two female subjects with a mean age of 20.36 $\pm$ 1.27yrs participated in this study. There were no significant differences in height, weight, BMI, and VO_{2max} between subjects in Phase I and Phase II. However, subjects were significantly younger ($p \leq 0.05$) in Phase I (19.88 $\pm$ 1.41 yrs) than those in Phase II (20.81 $\pm$ 0.98 yrs) (See Table 3.1).

Table 3.1 Subject Characteristics

Variable	**Phase I (n=16)**	**Phase II (n=16)**	**Combined Phase I & II (n=32)**
Age (years)	19.88 $\pm$ 1.41*	20.81 $\pm$ 0.98*	20.36 $\pm$ 1.27
Height (m)	1.63 $\pm$ 0.06	1.64 $\pm$ 0.07	1.63 $\pm$ 0.06
Weight (kg)	61.24 $\pm$ 7.05	59.20 $\pm$ 8.09	60.53 $\pm$ 7.63
BMI (kg/m^2)	23.10 $\pm$ 2.65	22.06 $\pm$ 2.27	22.78 $\pm$ 0.46
VO_{2max} (ml/kg/min)	39.91 $\pm$ 4.58	42.21 $\pm$ 5.47	40.66 $\pm$ 5.52

* Indicates statistically significant difference between Phase I and Phase II at $p \leq 0.05$

3.3 RECRUITMENT PROCEDURES

Potential subjects were recruited using informational flyers that were posted in the Stoner Complex, Aebersold Recreation Center, and the Student Union on Slippery Rock University's campus. Potential subjects who responded to the flyer had the nature, risk, and potential benefits of the investigation, as well as their rights as a research subject, explained to them. If a potential subject agreed to participate in the study and met the inclusion criteria, she was scheduled for a test date.

3.4 EXCLUSION CRITERIA

Subjects were excluded from participation if there was a contraindication to exercise testing as described by the American College of Sports Medicine Guidelines for Exercise Testing and Prescription (Appendix A). In addition, subjects were excluded for any of the following reasons:

1. Reporting regular exercise, including recreational sport, of greater than 60 min/day on more than 3 days per week during the previous six months.
2. Reporting previous perceived exertion scaling experience.
3. History of diabetes, hypothyroidism, or other medical conditions that would affect energy metabolism.
4. Women who were currently pregnant or those who were pregnant within the previous six months.
5. Non-medicated resting systolic blood pressure >160mmHg or non-medicated resting diastolic blood pressure >100mmHg, or taking medication that would affect blood pressure.
6. Taking medication that would affect resting heart rate or the heart rate response during exercise (e.g. beta blockade).
7. History of myocardial infarction or valvular disease.
8. History of orthopedic complications that would prevent complete participation in the exercise tests (e.g. heel spurs, severe arthritis).
9. Body Mass Index (BMI) >30 kg/m^2.
10. Male gender.

All participants completed a detailed medical history form (Appendix B) and the Physical Activity Readiness Questionnaire (PAR-Q) (Appendix C) prior to participating in this study. If the medical history indicated any contraindications to exercise testing or if the subject answered YES to any of the PAR-Q questions, the subject was excluded from this study. Subjects received $20.00 for their participation.

3.5 EXPERIMENTAL DESIGN

This investigation employed a two phase multiple observation, cross-sectional experimental design. Sixteen subjects from a primary pool were randomly assigned to experimental Phase I and 16 subjects were randomly assigned to experimental Phase II. The purpose of Phase I (n = 16) was to (a) determine the concurrent validity of the Physical Activity Index (PAI) and (b) develop a model to estimate walking kcal expenditure using the PAI score as a predictor variable. The purpose of Phase II (n = 16) was to (a) validate the PAI kcal prediction model and (b) compare kcal estimated by the PAI model to kcal estimated by the SenseWear Pro Armband™.

Phase I (n = 16):

1) PAI vs. VO_2 and heart rate
   - Concurrent validation across walking intensities
2) PAI vs. kcal expenditure
   - Develop model to predict kcal expenditure from PAI

Phase II (n = 16):

1) PAI_{kcal} vs. Respiratory $Metabolic_{kcal}$
   - Validation of model from Phase I
2) PAI_{kcal} vs. $Armband_{kcal}$
   - Comparison between kcal prediction procedures

Figure 3.1. Phase I and II of the Experimental Design

In step one of Phase I, concurrent validation was established by determining the relation between PAI score and VO_2 and HR for three walking intensities. It was hypothesized that as VO_2 and HR increased, so would the PAI score. In step two of Phase I, a statistical model was developed to predict kcal expenditure using the PAI score as the predictor variable (See Figure 3.1).

In step one of Phase II, the model was validated by determining the relation between the predicted kcal from the PAI model (developed in Phase I) and measured kcal determined by indirect calorimetry for each of the three walking intensities. Once validity of the PAI was established, step two of Phase II compared kcal expenditure predicted from the PAI model with kcal expenditure predicted from the Armband (See Figure 3.1).

Phase I of this investigation employed a within subject experimental paradigm consisting of one Aerobic Fitness Session (day 1) and one Exercise Session (day 2) (See Figure 3.2). The Aerobic Fitness Session was conducted first and consisted of a single load-incremented treadmill test to determine maximal oxygen consumption (VO_{2max}). The Exercise Session (day 2) consisted of three separate treadmill exercise bouts of varying walking intensities presented in counterbalanced order. Phase II used a separate cohort of subjects who performed the same Aerobic Fitness Session and Exercise Session as Phase I. During the Exercise Session (day 2) in Phase II, the SenseWear Pro Armband™ was used to estimate kcal expenditure. The Aerobic Fitness and Exercise Sessions of both phases lasted approximately one hour and were separated by five to seven days to allow adequate recovery. All testing was undertaken at the same time of day for each subject. All data collection took place in the Exercise Physiology Laboratory at Slippery Rock University.

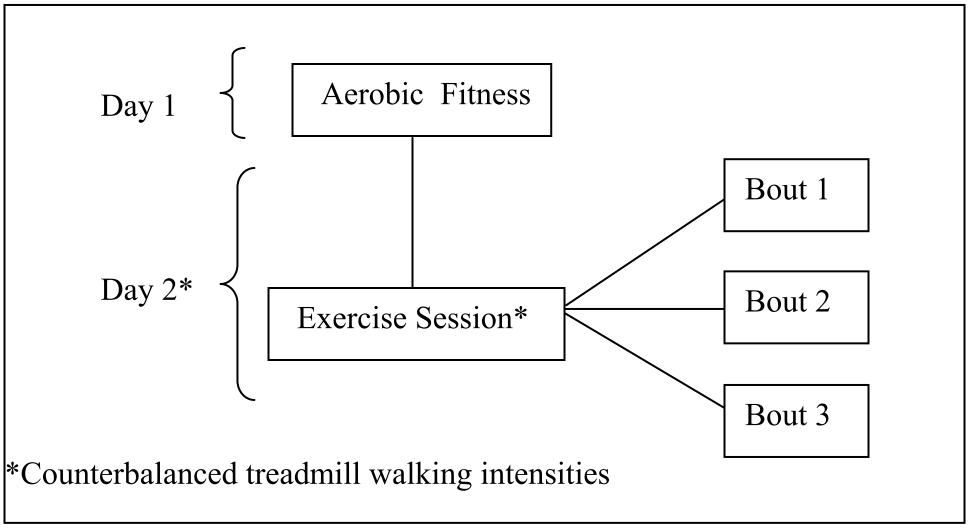


Figure 3.2. Testing Sequence for both experimental phases

3.6 ASSESSMENT PROCEDURES

3.6.1 Aerobic Fitness and Exercise Sessions

All subjects participated in an Aerobic Fitness Session and an Exercise Session. During the initial portion of the Aerobic Fitness Session, anthropometric measurements including height (cm) and weight (kg) were obtained. Following these measurements, each subject underwent OMNI-RPE scale orientation including a definition of perceived exertion, rating instructions and anchoring procedures using a memory technique (Appendix E). Lastly, maximal oxygen consumption (VO_{2max}) was determined via treadmill exercise testing using indirect calorimetry. This maximal test was administered on a Trackmaster TMX 425C treadmill (Newton, KS). A load-incremented Bruce treadmill protocol was employed which consisted of progressive three minute stages. Treadmill speed and grade were as follows: Stage 1, 2.73 $km \cdot hr^{-1}$ at 10% grade;

Stage 2, 4.03 km·hr^{-1} at 12% grade; Stage 3, 5.47 km·hr^{-1} at 14% grade, Stage 4, 6.76 km·hr^{-1} at 16% grade; Stage 5, 8.05 km·hr^{-1} at 18% grade.

Criteria to establish VO_{2max} included any three of the following:

1. Plateau in VO_2, where there was <2.1 ml · kg^{-1}· min^{-1} change in VO_2 with increasing exercise intensity at or near maximal treadmill stages.
2. Respiratory Exchange Ratio of $\geq$1.10.
3. Heart rate within $\pm$ 5 beats/min of age predicted maximal heart rate.
4. Volitional termination on part of the subject owing to fatigue.
5. OMNI Scale RPE-Overall of 9 or 10.

Following termination of the maximal treadmill test, subjects underwent a cool down period consisting of treadmill walking at 3.22 km·hr^{-1} at 0% grade, continuing until heart rate decreased to <110 beats/min. During the treadmill test, heart rate, VO_2, and RPE-Overall (RPE-O) were recorded. This information was used to determine the aerobic fitness level of each subject and established the relative metabolic intensity (i.e. % VO_{2max}) for each of the three walking bouts.

Five to seven days following the Aerobic Fitness session, the subject participated in the Exercise Session which consisted of three counterbalanced bouts of walking exercise on a Trackmaster TMX 425C treadmill (Newton, KS). Each walking bout was 10 minutes in duration, separated by 5 minutes of rest. During the rest period, subjects were seated on a bench, which was straddled across the treadmill, and heart rate was monitored. The three bouts of exercise consisted of the following speeds and grades: (a) 4.02 km·hr^{-1} at 0% grade, (b) 5.63 km·hr^{-1} at 2.5% grade, and (c) 7.24 km·hr^{-1} at 5% grade. Previous research in the Center for Exercise and Health-Fitness Research indicated that these exercise bouts are approximately equivalent to 30%, 55%, and 80% of VO_{2max} for female subjects having age, physical, and exercise characteristics similar to those that were involved in this investigation (Weary et al., 2006). These percentages of VO_{2max} were chosen because they elicited significant physiological and perceptual differences between low intensity (30%), moderate intensity (55%), and high intensity (80%) bouts of walking exercise (Weary et al., 2006). During each exercise minute for Phases I and II testing, HR, VO_2, pedometer step count, and RPE-Overall were recorded. During Phase II, SenseWear Pro Armband™ kcal expenditure was computed at one minute intervals and was recorded as the total kcal expended during each of the three 10 minute bouts of walking exercise.

3.6.2 Experimental Variables

The following variables were measured:

Weight: Body weight (kg) was assessed using the standard mode on an electronic Tanita bioelectrical impedance analyzer. This measure was taken during the Aerobic Fitness Session. Subjects wore light-weight exercise clothes consisting of shorts and a T-shirt. Shoes were not worn. Weight was recorded to the nearest 0.5 kg.

Height: Height (cm) was measured using a Detect-Medic Stadiometer (Detecto Sales Inc., New York), at the beginning of the Aerobic Fitness Session. Height was recorded to the nearest 0.25 cm.

Pedometer Step Count: During each walking bout of the Exercise Session, the Yamax Digi-Walker SW-701™ pedometer was positioned on the subject's waistband at the level of the umbilicus and in line with the anterior, vertical midline of the right thigh, consistent with the manufacturers' recommendations. Immediately at the termination of each of the three 10 minute walking bouts, the total number of steps taken was recorded. The pedometer was reset to zero prior to the start of each walking bout. The subjects were not informed of their pedometer step counts during the Exercise Session.

Ratings of Perceived Exertion (RPE): The adult version of the OMNI Walk/Run Perceived Exertion Scale (0-10) (Appendix D) was used to assess the subjects' rating of perceived exertion for the overall body (RPE-O) during each exercise bout. The RPE was reported as a whole number from 0-10, with 0 indicating no exertion and 10 indicating maximal exertion. RPE was measured for the last 15 seconds of each minute of exercise during both the Aerobic Fitness Session and the Exercise Session. Prior to exercise, the subjects were oriented to the OMNI Walk/Run Perceived Exertion Scale (Categories 0-10) using standardized instructions and anchoring procedures (Appendix E). These instructions were short, easily understood, and specific to the mode of exercise the subject performed. The instructions satisfied the basic requirements of Borg's Range Model for category rating scales. The instructions identified the lowest verbal and pictorial descriptors and numerical category on the scale and linked each to the subject's memory of the exertion associated with a very low exercise intensity. If the subject felt like the level of exertion indicated by the lowest verbal and pictorial descriptor, she pointed to a zero (0). The instructions then identified the highest verbal and pictorial descriptors and numerical category on the scale and linked each to the subject's memory of the exertion associated with a maximal exercise intensity. If the subject felt like the level of exertion indicated by the highest verbal and pictorial descriptor, she pointed to a ten (10). If the subject felt somewhere between 0 and 10, she pointed to a number between 0 and 10 indicating her perceived exertion.

The following memory anchoring procedures were used to reinforce the subject's ability to link exertional intensity with low and high OMNI scale categories. With the OMNI scale in full view, the subject was asked to recall a time when she felt no exertion at all (i.e. sitting). This exertion was assigned a "0" on the OMNI scale. Next, the subject was asked to recall a time when she experienced maximal exertion (i.e. the most strenuous walking and/or running exercise ever performed). This exertion was assigned a "10" on the OMNI scale.

Physical Activity Index (PAI): The PAI score was determined for each walking bout of the Exercise Session. The subject was asked to point to a numerical scale category for the overall body (RPE-O) during each minute of each walking bout. The mean of the minute-by-minute RPE for each walking bout was calculated. The PAI score was then calculated by multiplying total pedometer step counts for 10 minutes and mean RPE-O obtained for each walking bout. These indices indicated the total exercise load [i.e. volume (steps) x intensity (RPE)] undertaken during each bout.

SenseWear Pro Armband™ Kcal Expenditure: Kcal expenditure was also estimated using a calibrated SenseWear Pro Armband™ during each bout of the Exercise Session for subjects in Phase II of the experiment. As recommended by the manufacturer, the SenseWear Pro Armband™ was worn on the right arm over the triceps muscle at the midpoint between the acromion and olecronon processes. Upon entering the laboratory, the armband was placed on the subject's arm, according to specifications. The armband was worn with the subject in a seated position for 15 minutes prior to data collection. This was a manufacturer's requirement to equilibrate skin temperature with the unit's thermal sensor. Armband estimates of kcal expenditure during exercise were computed at one minute intervals during each of the three walking bouts in the Exercise Session. Kilocalories were summed over the ten minutes to yield the total number of kcal expended during each of the three walking bouts. Kcal expenditure of each walking bout was estimated using a generalized proprietary algorithm developed by the manufacturer. This estimated measurement of energy expenditure was compared with the estimated energy expenditure calculated using the PAI model developed in Phase I.

Heart Rate and Oxygen Consumption: Heart rate (beats/min) was measured with a Polar Monitoring System (Woodbury, NY) from 45-60 seconds of each minute during the Aerobic Fitness Session and during each minute of the three submaximal walking bouts of the Exercise Session. An open-circuit respiratory metabolic system (True Max 2400, Parvo Medics, Salt Lake City, UT) was used to measure total body VO_2 during each exercise minute of the Aerobic Fitness Session and Exercise Session. The respiratory-metabolic system was calibrated prior to each data collection session. Total kcal expenditure for each walking bout was determined from VO_2 by using a non-protein respiratory exchange ratio conversion table for energy substrate utilization (Zuntz, 1901).

3.7 DATA ANALYSES

Data analysis was conducted using SPSS statistical software, with probability of significance set at $p \leq 0.05$. The data was initially analyzed using descriptive statistics, including mean, standard deviation, range, and tests for normal distribution. In Phase I, Pearson correlations were used to analyze the relation between the PAI score and both HR and VO_2 determined by indirect calorimetry for each walking bout. The bivariate correlation analyses examined concurrent validity of the PAI. In addition, a multiple regression analysis was used to develop a model to predict walking kcal expenditure from each PAI score (i.e. for low, moderate, and high walking intensities). In Phase II, data was analyzed using a two-factor repeated measures ANOVA with total kcal expenditure serving as the dependent variable. The main effects in the factorial analysis were method of kcal measurement (indirect calorimetry, PAI, SenseWear Pro Armband™) and walking intensity (low, moderate, high). Significant main and interaction effects were decomposed with a simple effects *post hoc* procedure. Also in Phase II, a Pearson correlation was used to determine the relation between estimated PAI kcal expenditure (using the PAI model developed in Phase I) and actual kcal expenditure measured via indirect calorimetry. A Bland-Altman plot was constructed to show the distribution of the individual (criterion – comparison) scores around zero. The mean difference (criterion – comparison) is illustrated in these plots and the 95% prediction interval (confidence interval) is also shown (Figure 4.4). A second Bland-Altman plot was constructed to examine differences on the individual level between the PAI model and the Armband (Figure 4.4). Lastly, a Pearson correlation was used to determine the relation between estimated PAI kcal expenditure and estimated SenseWear Pro Armband™ kcal expenditure.

3.8 POWER ANALYSIS

Power analysis was conducted to determine sample size based on the ability to detect significant interactions within the ANOVA as determined by previous pilot data (Weary et al., 2006). Using a power of 0.80, an α of 0.05, and an effect size of 0.8, it was determined that a minimum of 16 females were required to test the main effects within a factorial analysis. A factorial analysis was run for Phase I and Phase II, thus 32 subjects were required. In addition, using a power of 0.80, an α of 0.05, and an effect size of 0.8, it was determined that a minimum of 13 subjects were required for the regression analysis to be used in Phase I. As such, a total of 32 females were tested in this investigation.

4.0 RESULTS

The primary purposes of this investigation were to examine the validity of the Physical Activity Index (PAI) as (a) a measure of total activity load (i.e. volume of exercise x intensity of exercise) and (b) as an estimate of total kcal expenditure during submaximal treadmill walking. A secondary purpose was to compare estimated kcal expenditure determined by the PAI prediction model to the estimated kcal expenditure determined by the SenseWear Pro Armband™.

This investigation employed a two phase multiple observation, cross-sectional experimental design. Thirty two females comprised the primary subject pool. Sixteen subjects were randomly assigned to experimental Phase I and 16 subjects were randomly assigned to experimental Phase II. The purpose of Phase I (n = 16) was to (a) determine the concurrent validity of the Physical Activity Index (PAI) and (b) develop a model to estimate walking kcal expenditure using the PAI score as a predictor variable. The purpose of Phase II (n = 16) was to (a) validate the PAI kcal prediction model that had been developed in Phase I and (b) compare kcal estimated by the PAI model to kcal estimated by the SenseWear Pro Armband™.

4.1 DESCRIPTIVE DATA

Descriptive data for HR, VO_2, and RPE were calculated as mean $\pm$ SD for low, moderate, and high walking intensities in each of the two phases. Two-factor (Intensity x Phase) ANOVAs were performed on HR, VO_2, and RPE. The ANOVA indicated significant main effects of intensity for HR ($F_{2,30}$ = 51.318, $P < 0.01$), VO_2 ($F_{2,30}$ = 131.876, $p < 0.01$) and RPE ($F_{2,30}$ = 34.82, $p < 0.01$). The main effect of Phase was not significant for HR ($F_{1,15}$ = 1.013, $p = 0.33$), VO_2 ($F_{1,15}$ = 0.11, $p = 0.92$), or RPE ($F_{1,15}$ = 0.29, $p = 0.60$). The Intensity x Phase interaction effects were not significant for HR ($F_{2,30}$ = 235.79, $p < 0.01$), VO_2 ($F_{2,30}$ = 0.14, $p = 0.87$) or RPE ($F_{2,30}$ = 1.37, $p = 0.27$). Mauchly's tests of sphericity for repeated measures of Intensity within Phase were not significant. The factorial analysis indicated that (a) there was a significant difference between each exercise intensity for HR, VO_2, RPE, and step count with the four variables increasing as walking intensity increased (Table 4.1) and (b) there were no significant differences in HR, VO_2, RPE, and Step Count between Phase I and Phase II within each exercise intensity level. This later analysis indicated that the perceptual and physiological responses at each walking intensity were similar for subjects used in experimental Phase I and Phase II.

Table 4.1 Means ± SD for physiological and perceptual variables during low, moderate and high intensity walking

		Low Intensity* (26% VO_{2max})	Moderate Intensity* (47%VO_{2max})	High Intensity* (88%VO_{2max})
Phase I	**HR (bpm)**	120.80 ± 12.14	144.93 ± 14.74	186.25 ± 7.67
	VO_2 (ml/kg/min)	11.56 ± 1.62	19.54 ± 1.88	36.31 ± 3.92
	RPE (0-10)	1.59 ± 0.64	3.37 ± 0.88	6.71 ± 0.92
	Step Count	971.44 ± 142.62	1214.19 ± 99.25	1426.13 ± 164.21
Phase II	**HR (bpm)**	113.94 ± 14.86	139.25 ± 12.72	183.25 ± 8.61
	VO_2 (ml/kg/min)	11.40 ± 0.96	18.84 ± 1.90	35.62 ± 4.75
	RPE (0-10)	1.66 ± 0.64	3.13 ± 1.18	6.14 ± 1.41
	Step Count	972.69 ± 237.66	1212.75 ± 58.73	1429.44 ± 143.79

* Indicates a significant difference between intensities at $p \leq 0.05$ for HR (heart rate), VO_2 (oxygen uptake), and RPE (rating of perceived exertion – overall body).

4.2 PHASE I: CONCURRENT PAI VALIDITY

The Physical Activity Index was calculated as the product of pedometer step count and RPE for each of the three walking intensities. To determine concurrent validity of the PAI, VO_2 and HR were used as criterion variables in Phase I (n=16). Multiple regression analysis revealed a strong, positive relation between PAI and both VO_2 (r = 0.92) and heart rate (r = 0.84) when responses to all three intensities were entered into the regression models (See Figure 4.1 and Table 4.2). These responses established concurrent validity for the PAI during treadmill walking using both VO_2 and HR as criterion variables.

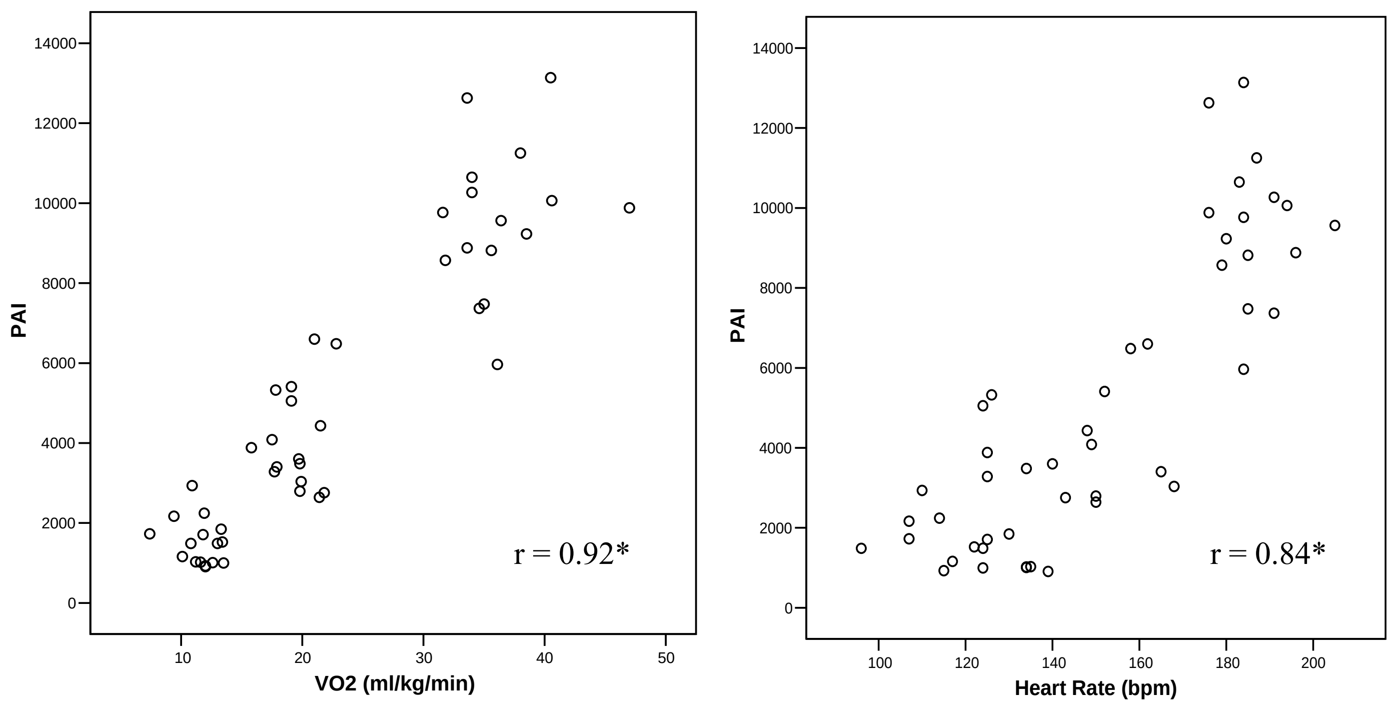


Figure 4.1. Regression analyses for relation between PAI (Physical Activity Index) and both oxygen uptake (VO_2) and heart rate (HR). $^*p < 0.05$

Table 4.2 Regression models for oxygen uptake (VO_2) and heart rate (HR) as a function of PAI scores across three walking intensities.						
Model	**Variable**	**Intercept**	**Slope**	**r**	**r^2**	**SEE**
I	VO_2	8.70	0.003	0.92	0.84	4.30
II	HR	115.77	0.007	0.84	0.71	16.11

4.3 PHASE I: MODEL DEVELOPMENT

A statistical model (III) to estimate kcal expenditure was developed using Phase I PAI scores (n=16) from the three separate 10 minute walking bouts. Model III was calculated using PAI data (steps x RPE) from the low, moderate, and high walking intensities where the relative metabolic was 28%, 47%, and 88% of VO_{2max} respectively.

Model III.

Predicted kcal = 28.056 + 0.006 (PAI score) $p < 0.05$**, SEE = 17.34, r = 0.80,** $r^2 = 0.64$

The regression analysis for Model III is also depicted in Figure 4.2.

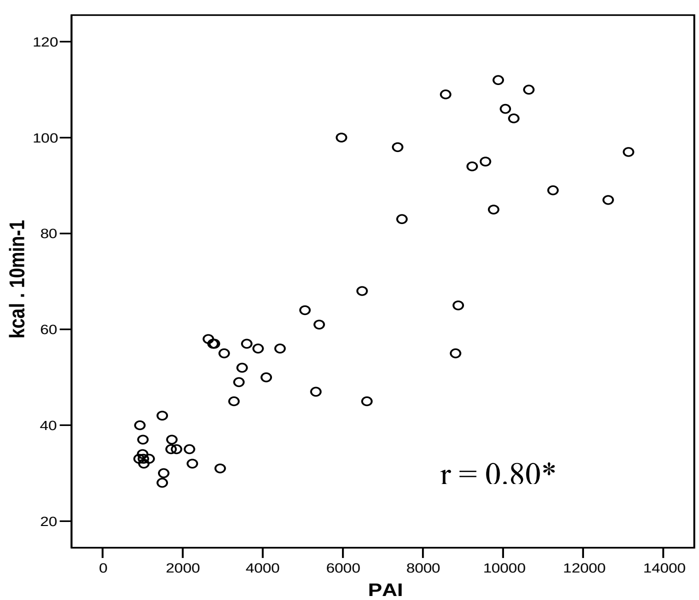


**Figure 4.2 Relation between predicted kcal (kilocalorie) expenditure and PAI (Physical Activity Index) across low, moderate and high walking intensities. *** $p < 0.05$

4.4 PHASE II: MODEL VALIDATION

The PAI scores of Phase II subjects (n=16) were individually entered into Model III. In this procedure, Model III was used to predict kcal expenditure for 10 minute periods of walking at low, moderate and high intensities for each Phase II subject. Next, to determine the accuracy of Model III, predicted kcal expenditure (i.e. from Model III) was regressed against kcal expenditure actually measured using indirect calorimetry (Model IV). Measured kcal expenditure was determined from oxygen consumption adjusted for energy substrate metabolism using the respiratory exchange ratio. Kcal expenditure was calculated for each individual at one minute intervals and then summed for each of the three 10 minute bouts of walking exercise. The regression analysis (Model IV) revealed a strong, positive correlation (r = 0.85; $p < 0.01$) between measured kcal expenditure and predicted kcal expenditure from Model III (Figure 4.3).

Model IV.

Measured Kcal = 20.659 + 0.596 (Predicted kcal) $p < 0.01$, SEE = 10.69, r = 0.85, $r^2 = 0.72$

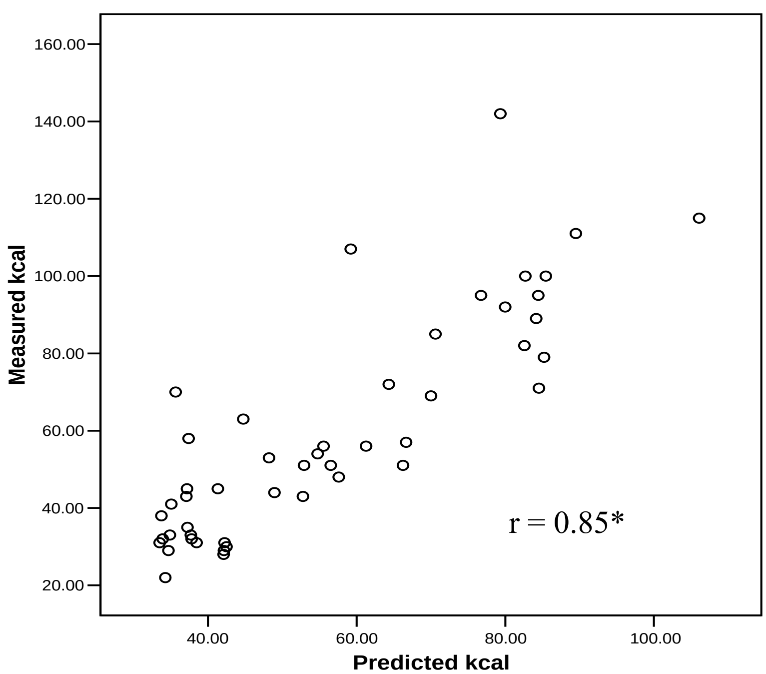


Figure 4.3 – Relation between kilocalorie (kcal) measured by indirect calorimetry and predicted using the PAI model III

Means and standard deviations for kcal expenditure measured by indirect calorimetry and predicted by Model III are shown in Table 4.3.

Table 4.3 Mean ± SD for measured and PAI predicted kilocalorie (kcal) expenditure for low, moderate, and high intensity walking exercise.

Method	Low (kcal)	Moderate (kcal)	High (kcal)
Measured	32.38 ± 5.08	52.81 ± 7.28	94.00 ± 18.96
Predicted	37.34 ± 3.32*	51.12 ± 9.84	80.31 ± 10.87*

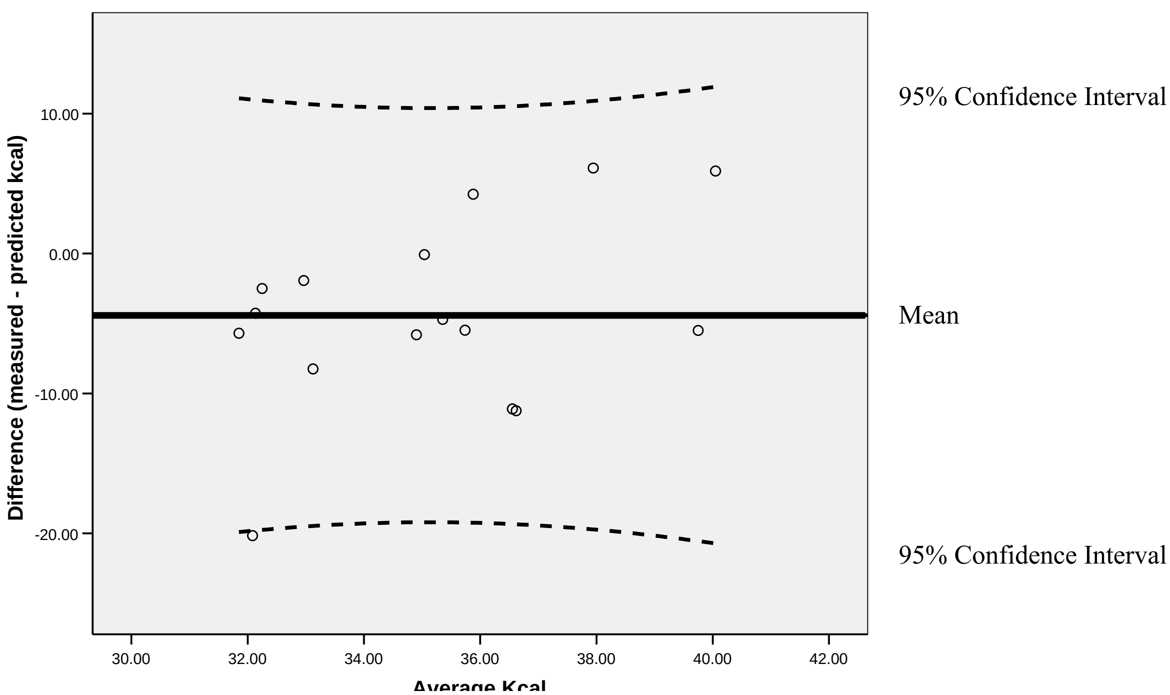
* Indicates a significant difference ($p < 0.05$) from measured kcal expenditure using indirect calorimetry.

A two-factor (Intensity: low, moderate, high x Method: measured, predicted) ANOVA was calculated for kcal expenditure. The ANOVA indicated significant main effects for intensity ($F_{2,30} = 191.82$, $p < 0.01$), and non-significant main effects for method of kcal measurement ($F_{1,15} = 1.42$, $p = 0.25$) (Table 4.3). The Intensity x Method interaction effect was significant for kcal expenditure ($F_{2,30} = 14.52$, $p < 0.01$). Mauchly's tests of sphericity for repeated measure of Intensity within Method were not significant. The *post hoc* analysis indicated that (a) there was a significant increase in kcal expenditure from low to moderate to high walking intensities when determined with both methods, (b) there were no significant differences in kcal expenditure between measured and predicted methods when examined at the moderate walking intensity and (c) PAI predicted kcal expenditure was greater than measured at low intensity and less than measured at high intensity. A dependent t-test compared the combined kcal expenditure (low, moderate, high) between the measured and predicted methods. The analysis indicated that there was no significant difference in combined kcal expenditure between measured (60.21 ± 27.39) and predicted values (57.40 ± 20.89) ($p = 0.06$).

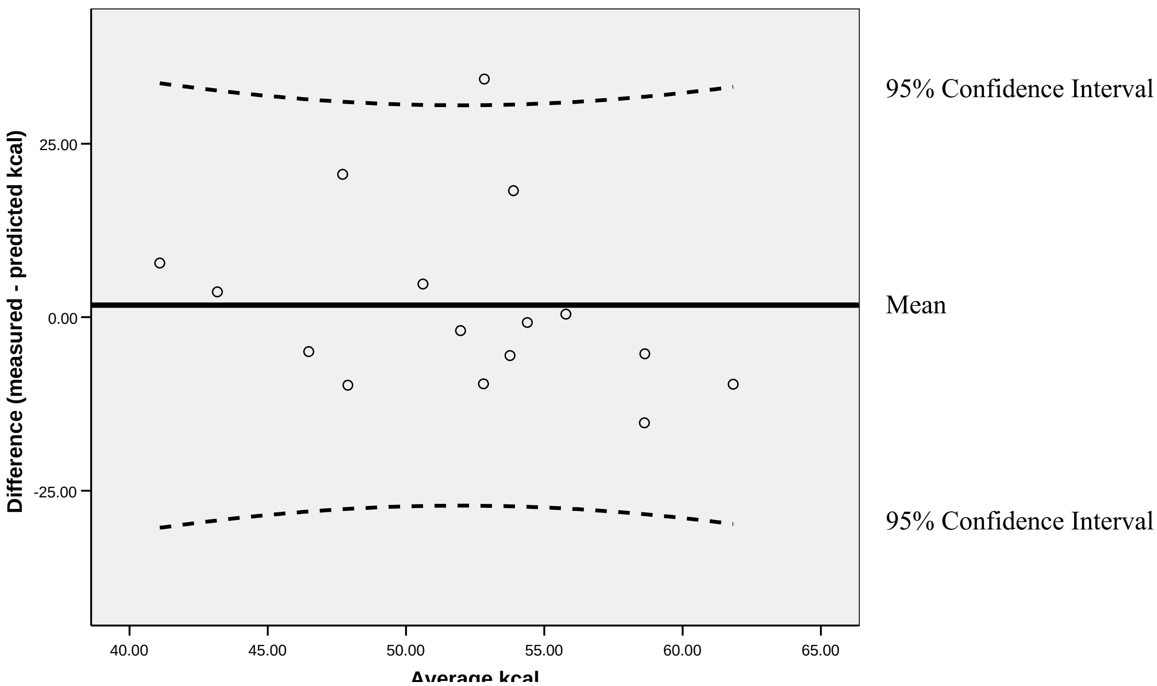
Bland-Altman plots were generated to assess the agreement between the two methods (Measured vs. Predicted) of determining kcal expenditure using data from the low, moderate and high walking intensities (See Figure 4.4). The *x* axis shows the mean of the responses from the two methods (Measured + Predicted / 2) for each subject. The *y* axis presents the absolute difference between the two methods ([Predicted - Measured]) for each subject. The confidence intervals were set at 95% (Mean ± 2 standard deviations).

The Bland-Altman plots indicated that Model III generally over-predicted kcal expenditure during low intensity walking exercise and under-predicted kcal expenditure during high intensity walking exercise (Figure 4.4). The Bland-Altman plots for moderate intensity walking indicated an approximately equal amount of over and under-predications of kcal expenditure using Model III (Figure 4.4).

Low intensity



Moderate Intensity



High intensity

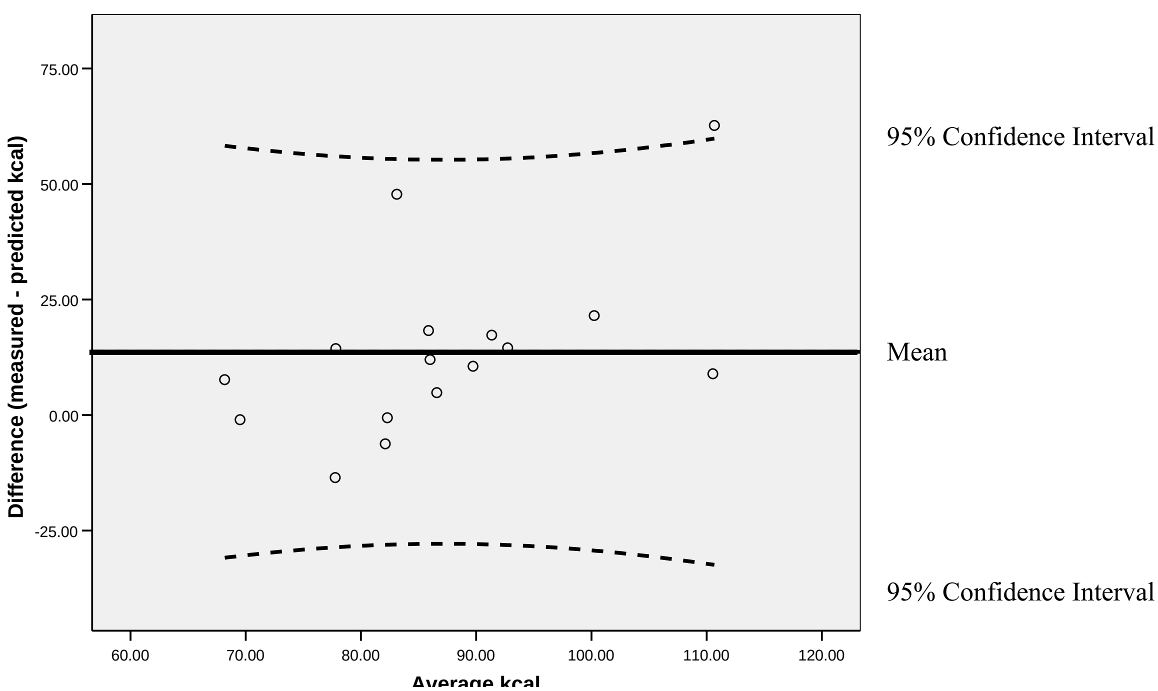


Figure 4.4 Bland-Altman plots depicting level of agreement between measured and predicted kilocalorie (kcal) expenditure during low, moderate, and high walking intensities

4.5 PHASE II: SENSEWEAR PRO ARMBAND™ VERSUS MEASURED AND PAI PREDICTED KCAL

Kcal expenditure was estimated by the SenseWear Pro Armband™ for the low, moderate, and high intensity exercise conditions. Multiple regression analysis revealed a strong, positive relation between estimated Armband kcal expenditure and measured kcal expenditure (r = 0.83; $p < 0.01$) using repeated measures data across the three walking intensities. Multiple regression analysis also indicted a strong, positive relation between estimated Armband kcal expenditure and PAI predicted kcal expenditure (r = 0.71; $p = 0.01$) (Figure 4.5).

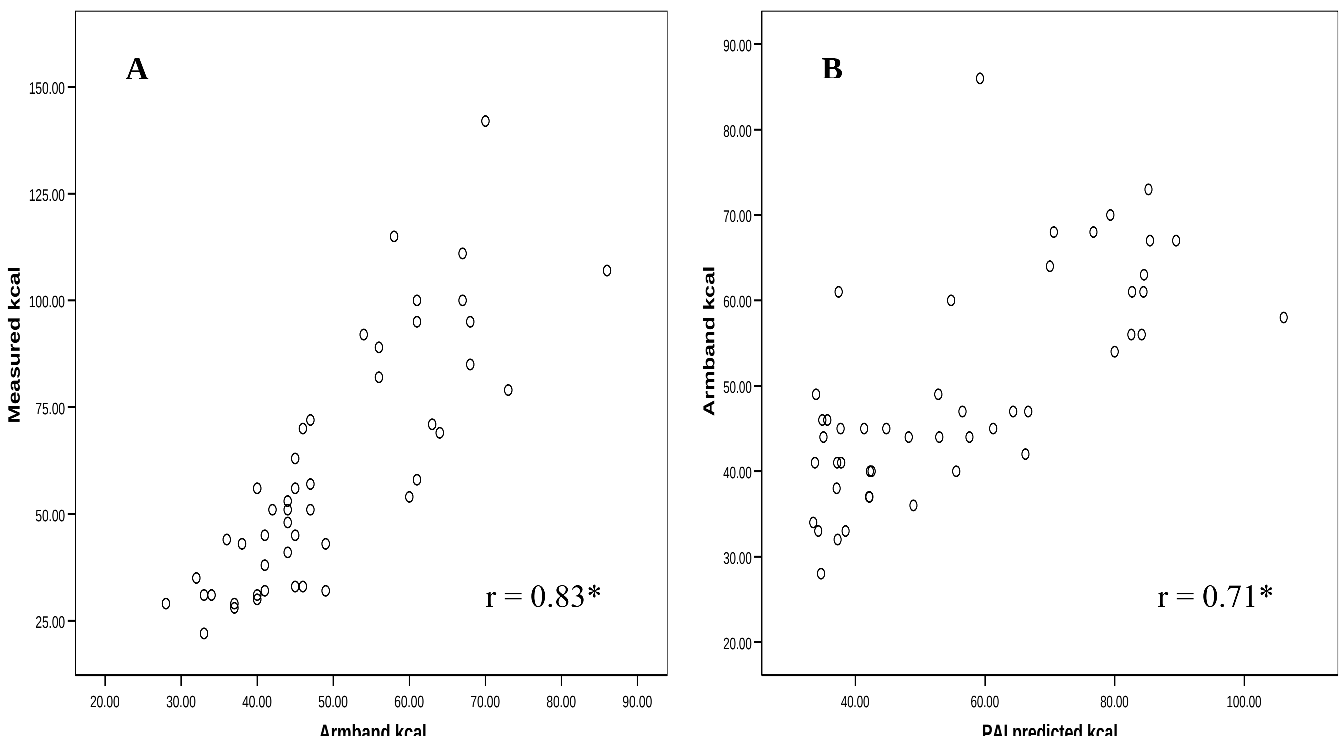


Figure 4.5 Relation between (A) estimated Armband kilocalorie (kcal) expenditure and measured kcal expenditure and (B) estimated Armband kcal expenditure and PAI predicted kcal expenditure. $^*p < 0.05$

A two-factor (Intensity: low, moderate, high x Method: Armband and measured) ANOVA was performed for kcal expenditure. The means ± SD for these data are presented in Table 4.4. The ANOVA indicated significant main effects for intensity ($F_{2,28} = 289.83$, $p < 0.01$)

and method ($F_{1,14}$ = 18.85, $p < 0.01$). The Intensity x Method interaction effect ($F_{2,28}$ = 45.71, $p < 0.01$) was also significant for kcal expenditure. Mauchly's tests of sphericity for repeated measures of Intensity within Method were not significant. The *post hoc* analysis of the intensity main effect indicated that kcal expenditure increased from low to moderate to high walking intensities when measured by both indirect calorimetry and the Armband. *Post hoc* analysis of the Intensity x Method interaction indicated that (a) kcal expenditure was significantly higher for Armband than measured methods at low intensity and (b) kcal expenditure was significantly lower for Armband than measured methods at the moderate and high walking intensities (Table 4.4).

Table 4.4 Mean ± SD for measured and Armband kcal expenditure across low, moderate and high walking intensities.

Method	Low (kcal)	Moderate (kcal)	High (kcal)
Measured	32.38 ± 5.08	52.81 ± 7.28	94.00 ± 18.96
PAI Predicted	37.34 ± 3.32*	51.12 ± 7.28	80.31 ± 10.87*
Armband	37.93 ± 5.20*	46.67 ± 6.08*	64.80 ± 8.12*

* Indicates a significant difference (p<0.05) from measured kcal expenditure using indirect calorimetry.

A two-factor (Intensity: low, moderate, high x Method: Armband and PAI) ANOVA was performed for kcal data derived from Phase II subjects. The means ± SD for these data are presented in Table 4.4. The ANOVA indicated significant main effects for Intensity ($F_{2,30}$ = 92.85, $p < 0.01$) and Method ($F_{1,15}$ = 12.29, $p = 0.01$). The Intensity x Method interaction effect ($F_{2,30}$ = 231.41, $p < 0.01$) was also significant for kcal expenditure. Mauchly's tests of sphericity for repeated measures of Intensity within Method were not significant. The *post hoc* analysis indicated that (a) kcal expenditure increased from low to moderate to high walking intensities when measured by both the PAI and Armband and (b) kcal expenditure did not differ between

Armband and PAI methods at the low and moderate intensities but was significantly lower for Armband than PAI at the high walking intensity (Armband 64.80 $\pm$ 8.13 kcal; PAI 80.03 $\pm$ 11.19 kcal; $p < 0.01$) (Table 4.4).

4.6 SUMMARY OF RESULTS

In Phase I, concurrent validation of the PAI was established using VO_2 and HR as the criterion variables. Multiple regression analyses revealed a strong, positive relation between PAI score and VO_2 (r = 0.92) and HR (r = 0.84) when data from all three walking intensities were entered into the prediction equations. Data derived from Phase I were then used to develop a statistical model to estimate kcal expenditure using the PAI score as the predictor variable. This regression equation (Model III) estimated kcal expenditure for a 10 minute bout of treadmill walking using PAI scores from Phase I subjects. The model to predict kcal expenditure from PAI score was:

Model III.

Predicted kcal = 28.056 + 0.006 (PAI score) $p < 0.05$, **SEE = 17.34, r = 0.80,** $r^2 = 0.64$

Phase II validated the use of Model III to predict kcal from PAI scores. Using Model III, kcal expenditure was predicted for individual subjects and regressed against the corresponding measured kcal values using data for the three walking intensities. Walking kcal expenditure predicted by Model III was highly correlated with measured kcal expenditure (r = 0.85). Armband predicted kcal expenditure also evidenced a strong, positive correlation with measured kcal expenditure (r = 0.83) when calculated across the three walking intensities. The kcal expenditure derived from the SenseWear Pro Armband™ was signficantly higher than that measured by indirect calorimetry for the low walking intensity and lower than that measured by indirect calorimetry for the moderate and high walking intensities.

5.0 DISCUSSION

The primary purposes of this investigation were to examine the validity of the Physical Activity Index (PAI) as, (a) a measure of total activity load (i.e. volume of exercise x intensity of exercise) and (b) as an estimate of total kcal expenditure during submaximal treadmill walking. A secondary purpose was to compare estimated kcal expenditure determined by the PAI prediction model to the estimated kcal expenditure determined by the SenseWear Pro Armband™.

5.1 PHASE I: CONCURRENT VALIDATION AND MODEL DEVELOPMENT

The purpose of Phase I of the investigation was to establish concurrent validity of the PAI for young, adult females performing treadmill walking that varied from low to high intensities. The PAI was calculated as the product of RPE and pedometer step count for each of three, 10 minute bouts of treadmill walking. Concurrent validity was established by determining the relation between PAI score and both VO_2 and HR for the three treadmill walking intensities. It was expected that as VO_2 and HR increased, so too would the PAI score. Concurrent validity of the PAI was evidenced by strong, positive correlations for both the VO_2 ($r = 0.92$) and HR ($r = 0.84$) criterion variables. Therefore, as the aerobic metabolic and circulatory demands of treadmill walking increased, so too did the PAI. These findings provided physiological validity evidence for the PAI as a measure of the total activity load (i.e. volume x intensity) for treadmill walking speeds that varied from low to high intensities.

Data derived from Phase I were also used to develop a statistical model to estimate kcal expenditure using the PAI score as the predictor variable. This regression equation (Model III; Chapter IV) estimated kcal expenditure for a 10 minute bout of treadmill walking using PAI scores from Phase I subjects.

Model III:

Predicted kcal = 28.056 + 0.006 (PAI score)	**$p < 0.05$, SEE = 17.34, r = 0.80, $r^2 = 0.64$**

The model demonstrated a positive and statistically significant correlation (r = 0.80) between PAI and kcal expenditure across treadmill walking intensities. The model explained 64% of the variance in kcal expenditure for treadmill walking at low, moderate, and high intensities.

5.2 PHASE II: MODEL VALIDATION

The purpose of Phase II of the investigation was to validate kcal prediction using Model III in an independent sample of young adult women. The individual PAI scores from Phase II subjects were entered into Model III to predict kcal expenditure. It was hypothesized that Model III would explain statistically significant amounts of variance in kcal expenditure for treadmill walking. To determine the accuracy of Model III, predicted kcal expenditure (i.e. from Model III) was regressed against corresponding kcal expenditure actually measured using indirect calorimetry (Model IV) for the 16 subjects in Phase II. The regression analysis (Model IV) revealed a strong, positive correlation (r = 0.85) between measured kcal expenditure and predicted kcal expenditure from Model III. The findings are generally consistent with those from a preliminary investigation that demonstrated a positive relation between PAI scores and measured kcal expenditure (r = 0.69) for selected walking and running treadmill speeds (Weary et al., 2006).

Bland-Altman plots were used to depict the level of agreement between measured and predicted kcal expenditure during low, moderate, and high walking intensities. The Bland-Altman plots indicated that Model III generally over-predicted kcal expenditure during low intensity walking and under-predicted kcal expenditure during high intensity walking. The plots for moderate intensity walking indicated an equal amount of over and under-predications of kcal expenditure using Model III. These results support the hypothesis that the PAI could be used to predict kcal expenditure for young women performing varying treadmill walking intensities. In summary, Model III was found to provide an accurate estimate of energy expenditure during treadmill walking at a moderate intensity. Prediction variability was somewhat greater at the lower and higher walking intensities.

Model III was calculated using combined data for the three walking intensities. Recognizing a tendency for such data to “regress to the mean”, the Model was more reflective of kcal expenditure at the moderate intensity than at the extremes of the intensity range studied. Although Model III was not as accurate at the low and high intensities, the findings indicated that the PAI provides a single valid measure to predict kcal expenditure over a range of walking intensities normally encountered in every day activities. These findings point to ecological application of the PAI for both health-fitness programming and public health assessment.

Energy expenditure derived from the PAI may have been over- and under-predicted at the low and high intensities respectively, due to limitations of the pedometer in detecting inter and intra-individual differences in gait cycles and stride length. Previous investigations have indicated that walking speed may have an effect on the accuracy of pedometer counts, distance covered, and predicted kcal expenditure. Crouter et al. (2003) found that pedometers were less accurate in measuring step counts at slower speeds (54 m/min) than at faster speeds (80 m/min). This inaccuracy of waist-mounted pedometers was due to less vertical acceleration of the waist at slow walking speeds (Crouter, 2003). For similar reasons, Crouter et al. suggests that electronic pedometers underestimate kcal expenditure during lifestyle activity such as gardening and housework (Crouter et al., 2003).

Step counts derived from pedometers generally evidence only moderate accuracy in estimating kcal expenditure during locomotor activity (Tudor-Locke, 2002). Thus, the current investigation employed an index that combined pedometer step counts with a perceptual measure of relative exercise intensity (i.e. RPE). It was expected that the calculated PAI would accurately predict kcal expenditure during treadmill walking when examined for young adult women. This was the case. The PAI computed as the product of pedometer step count and RPE provided a more accurate estimate of kcal expenditure (r = 0.85) than reported previously for pedometer step count alone (r = 0.68; Tudor-Locke, 2002).

5.2.1 Phase II – Armband Validation

In Phase II of the investigation, it was hypothesized that kcal expenditure estimated by the SenseWear Pro Armand™ would significantly correlate with measured and PAI predicted kcal expenditure. Armband predicted kcal expenditure evidenced strong, positive correlation with measured kcal expenditure (r = 0.83) and PAI predicted kcal expenditure (r = 0.71) using pooled data from the three walking intensities. These results supported the hypothesis that there would be a strong, positive correlation between kcal expenditure estimated by the SenseWear Pro Armband™ and both measured kcal expenditure and PAI predicted kcal expenditure. However, the ANOVA indicated that the SenseWear Pro Armband™ was slightly less accurate in predicting kcal expenditure than the PAI (i.e. Model III) for low, moderate, and high walking intensities.

5.3 COMPONENTS OF THE PAI

5.3.1 Pedometer Step Count

Pedometers provide a measure of the volume of physical activity for such ambulatory modes as walking and climbing stairs (Tudor-Locke et al., 2002). Tudor-Locke et al. (2002) reviewed twenty five published articles in which pedometers were compared to other methods of physical activity monitoring. Modest to high correlations were found between pedometer step counts and accelerometer step counts (r = 0.86), physical activity observation (r = 0.82), energy expenditure (r = 0.68), and self report questionnaires (r = 0.33).

Studies have shown that pedometers are most accurate at measuring steps taken (Bassett et al, 1996; Hendelman, Miller, Baggett, Debold, and Freedson, 2000), less accurate at estimating distance traveled (Bassett et al., 1996; Hendelman et al., 2000) and even less accurate at estimating kcal expenditure (Bassett et al., 2000). In addition, walking speed may have an effect on the accuracy of pedometers to measure step counts and distance covered, and to estimate kcal expenditure (Crouter et al., 2003).

Pedometers are comparatively less accurate at estimating kcal expenditure because they do not record velocity or intensity of movement. This restricts their use to measuring total accumulated steps/day for a given locomotor mode (President's Challenge Report, 2006). Although pedometers can be useful tools in promoting physical activity participation, they do not account for differences in exercise intensity and thus, do not accurately estimate kcal expenditure of locomotor activities. Because pedometers do not account for intra- and inter-individual differences in exercise intensity, it was proposed presently that the pedometer step count system be modified to include a measure of relative intensity. As such, the present investigation combined pedometer step counts with RPE to provide a more accurate measure of total activity load and associated kcal expenditure. The high correlations between PAI score and both aerobic metabolic and circulatory responses to variations in walking intensities supported the validity of this new procedure.

5.3.2 Ratings of Perceived Exertion

Ratings of perceived exertion (RPE) are indicators of the physical strain and associated subjective fatigue and discomfort experienced during dynamic and resistance exercise (Robertson, 2004). Borg's work in the late 1950's and early 1960's demonstrated a consistent positive relation between HR, VO_2 and RPE during load incremented protocols involving various modes of aerobic exercise. During dynamic exercise, the correlation between VO_2 and RPE ranges from $r = 0.76$ to $r = 0.97$ (Robertson, 2004; Noble, 1996).

Increases in VO_2 during most forms of aerobic exercise are associated with a corresponding increase in RPE (Robertson, 2004). Low intensity aerobic exercise results in a lower VO_2 with RPEs in the lower response zone (OMNI-RPE = 1 to 3). High intensity exercise results in a comparatively higher VO_2 with RPEs in the higher response zone (OMNI-RPE = 7/8 to 10). Numerous reports established that RPE and the percent of maximal oxygen uptake evidence a parallel and interdependent correspondence during dynamic exercise (Robertson et al., 2006). These findings support the basic premise of the present investigation that RPE provides a measure of the relative metabolic intensity of aerobic activities such as walking. As such, the present investigation employed RPE as a measure of relative exercise intensity when computing the PAI. The PAI score was then entered into a statistical model that estimated kcal expenditure for various walking intensities. It was concluded that such a psychophysiological tool allowed more precise estimations of kcal expenditure during treadmill walking with application to young adult women who were recreationally active.

5.3.3 Physical Activity Index

To more accurately estimate kcal expenditure, the current investigation proposed multiplying pedometer step count x RPE to calculate a PAI score. This PAI score was then used to develop a model to predict kcal expenditure using pooled data from three separate walking intensities. Previous research in the Center for Exercise and Health-Fitness Research indicated that these three walking intensities approximated 30%, 55%, and 80% of VO_{2max} for female subjects having age, physical, and exercise characteristics similar to those that participated in the present investigation (Weary et al., 2006). Weary et al. employed these relative metabolic rates because they elicited significant physiological and perceptual differences between walking intensities (Weary et al., 2006). In the present investigation, the oxygen consumption was 28% of VO_2max at low intensity, 67% at moderate, and 88% at the high walking intensity. It would be expected that most daily activities involving walking fall within this relative metabolic range. As such, the PAI provided a practical and inexpensive means to estimate kcal expenditure during walking exercise at metabolic rates that ranged from comparatively low to high levels.

5.4 CURRENT KCAL PREDICTION MODELS

Equations to estimate kcal expenditure have been created using pedometer step counts, accelerometer values, and RPE as predictor variables. It was hypothesized presently that an index calculated as the product of step count and RPE would provide a comparatively more accurate estimate of kcal expenditure during treadmill walking at varying intensities. The strong, positive correlation between PAI scores and measured kcal expenditure for Model III (r = 0.80) supported this expectation.

5.4.1 Pedometer kcal prediction models

Tudor-Locke et al. (2002) reported a moderate relation (r = 0.68) between pedometer estimated kcal expenditure and kcal expenditure measured via indirect calorimetery. Welk et al. (2000) found moderate correlations between Digi-Walker pedometer step counts and measured kcal expenditure when data were analyzed for thirty-one adults. It was concluded that pedometers provide a useful indicator of daily step counts, however variability in exercise intensity and movement patterns make it difficult to establish step count guidelines that correspond with public health guidelines regarding the energy expenditure of health-related physical activity (Welk et al., 2000).

In the present investigation, the PAI (i.e. Model III) provided an accurate estimate of kcal expenditure by accounting for both the volume of activity (i.e. step count) and the relative walking intensity (i.e. RPE). The current investigation found a strong, positive relation (r = 0.85) between PAI estimated kcal expenditure and measured kcal expenditure for an independent group of young adult women. This correlation is higher than the moderate relation (r = 0.68) between pedometer estimated kcal expenditure and measured kcal expenditure reported by Tudor-Locke (2002). These findings indicate that an adaptation to the pedometer step count system that employs RPE provides a comparatively more accurate estimate of kcal expenditure during walking at low, moderate, and high intensities.

5.4.2 RPE based kcal prediction models

Intensity is an important factor in estimating kcal expenditure of physical activity. Because RPE is related to the relative aerobic metabolic rate (Robertson, 2004), it has been used in both single and multivariate regression equations to estimate energy expenditure during various types of aerobic exercise. However, no known kcal prediction equation has been published that validates RPE as a primary predictor of kcal expenditure during walking at various intensities. As such, the present investigation combined RPE with pedometer step counts to more accurately predict kcal expenditure in young, adult women performing various walking intensities.

5.4.3 Accelerometer kcal prediction models

Bassett et al. (2000) reported a low to moderate relation (r = 0.33 to r = 0.62) between kcal estimated by three models of the CSA accelerometer and kcal expenditure measured via indirect calorimetery. In general, the accelerometers tended to overpredict kcal expenditure during most walking speeds (Bassett et al., 2000). However, accelerometers underpredicted the energy cost of many other activities such as lawn mowing and household sweeping (Bassett et al., 2000). It was speculated that this inaccuracy was because of an inability of a waist-positioned accelerometer to detect arm movements, thereby limiting measures of external work performed (Bassett et al., 2000). In addition, Crawford et al., (2004) examined the validity of the SenseWear Pro Armband™ to assess energy expenditure during various modes of aerobic exercise. Crawford et al. (2004) reported that the Armband significantly underestimated kcal expenditure during low and moderate intensities of cycle and treadmill exercise in male and female adolescents.

The current investigation reported findings similar to those of Bassett et al. (2002) and Crawford et al. (2004). The pairwise comparisons indicated that the SenseWear Pro Armband™ was less accurate in predicting kcal expenditure than the PAI (Model III) for low, moderate, and high walking intensities. Previous investigations illustrate the limitations of using accelerometers such as the SenseWear Pro Armband™ to predict kcal expenditure in free-living environments (Crawford, 2004, Bassett, 2000, King 2004). Possible mechanisms underlying the over- and underestimation of energy expenditure by the Armband are complex but may include: the use of generalized exercise algorithms to predict all types of physical activity; the delay in body heat transfer to the skin; and the inability to account for variability in walking gait, lean body mass and fat mass. All of these factors impact the accuracy of the Armband to estimate kcal expenditure (Crawford, 2004; Bassett, 2000; King 2004).

5.4.4 PAI kcal prediction models

Only one previous investigation has examined the validity of a kcal prediction equation using the PAI (Steps x RPE) (Weary et al., 2006). In this previous pilot investigation, a moderately strong positive relation was found between PAI score and measured kcal expenditure (r = 0.69) for selected walking and running treadmill speeds (Weary et al., 2006). Similarly, the current investigation demonstrated a strong positive relation (r = 0.85) between kcal expenditure predicted from the PAI score (Model III) and kcal expenditure measured via indirect calorimetry. This finding indicates that the PAI accurately predicts kcal expenditure for recreationally active young adult women during varying walking intensities.

The PAI method of predicting kcal expenditure evidenced a stronger relation (r = 0.85) to measured kcal expenditure than has been reported previously for the pedometer method (r = 0.68; Tudor-Locke et al., 2002). These findings indicate that statistical models to estimate energy requirements of walking should take into consideration both volume and intensity of exercise. The PAI method of estimating kcal expenditure uses a multiplicative format consisting of a measure of activity volume (i.e. step count) and relative intensity (i.e. RPE). Because the calculated PAI represents the total work being performed (volume x intensity), it more accurately estimates kcal expenditure. Based on the present findings, this conclusion is generalizable to young adult women walking on a treadmill at varying intensities.

In addition to its accuracy, the PAI method of estimating kcal expenditure is inexpensive, unobtrusive and has low subject and investigator burden. These measurement attributes make the PAI an easily applicable public health tool that will assist the lay individual in estimating walking kcal expenditure.

5.5 SENSEWEAR PRO ARMBAND ™ VS. MEASURED KCAL EXPENDITURE

A secondary purpose of this investigation was to compare kcal expenditure estimated by the PAI (Model III) to the kcal expenditure estimated by the SenseWear Pro Armband™. Both PAI and Armband methods of estimating kcal expenditure were correlated with actually measured kcal expenditure to determine which method was most accurate. It was hypothesized that both the PAI and Armband methods would be highly correlated with measured kcal expenditure.

The SenseWear Pro Armband™ adjusts for interindividual differences in gender, age, height, weight, handedness, and smoking status of the subject and uses proprietary algorithms developed by the manufacturer to estimate energy expenditure (Feo et al., 2005). Multiple regression analysis revealed a strong, positive relation between estimated Armband kcal expenditure and measured kcal expenditure ($r = 0.83$; $p < 0.01$) for data collapsed across the three walking intensities. However, analysis of variance revealed that kcal expenditure was significantly different between Armband and measured methods at the low, moderate, and high walking intensities. A *post hoc* analysis revealed that the Armband generally over-predicted kcal expenditure at the low intensity and under-predicted kcal expenditure at the moderate and high intensities for the women studied.

Several other Armband validation studies have reported results similar to those observed presently. Jakicic et al. (2004) reported that the SenseWear Pro Armband™ significantly underestimated total energy expenditure by (mean $\pm$ SD) 14.9 $\pm$ 17.5 kcal (6.9 $\pm$ 8.5%) during walking exercise (Jakicic, et al., 2004). In addition, Cole et al. reported that a moderate, positive correlation was found between kcal expenditure measured with indirect calorimetry and estimated by the Armband ($r = 0.67$) for treadmill walking (Cole et al., 2004). Some investigators have proposed that the SenseWear Pro Armband™ can be used as a motivational tool to promote physical activity participation (Jakicic, 2004). However, the data derived presently indicate that the Armband should be used cautiously when energy expenditure is the focal point of physical activity interventions that involve walking.

5.5.1 SenseWear Pro Armband™ versus PAI kcal expenditure

The current investigation used kcal expenditure measured by indirect calorimetry as the criterion variable to evaluate the prediction validity of both the PAI and SenseWear Pro Armband™. Correlations between measured kcal expenditure and estimated kcal expenditure were $r = 0.85$ for the PAI and $r = 0.83$ for the Armband. The ANOVA for these data revealed that kcal expenditure did not differ between Armband and PAI methods at the low and moderate intensities but was significantly lower for Armband than PAI at the high walking intensity. The Armband did not appear to be a sensitive measure of energy expenditure during high intensity walking in comparison to the PAI.

Therefore, the PAI may be more accurate than the Armband in predicting kcal expenditure at faster walking speeds. If so, individuals who are seeking to increase physical activity levels may employ the PAI as a less expensive and more accurate means to track kcal expenditure during higher intensity walking exercise.

Due to the reported inconsistencies of the Armband kcal measurements and its comparatively high cost, the unit may not always be the method of choice for locomotor activity assessment. In contrast, the present findings suggest that the PAI (Model III) may be a preferable procedure to estimate kcal expenditure for young women walking at varying intensities. The PAI Model III not only accounts for differences in walking intensities and more accurately estimates kcal expenditure, but it is comparatively less expensive and easier for general public use.

5.6 PAI APPLICATION

It was anticipated that the PAI would provide an easy and inexpensive means to estimate kcal expenditure during walking exercise in young adult, recreationally active females. The PAI is unobtrusive, inexpensive and provides low subject and investigator burden as compared to current commercially available instruments such as the SenseWear Pro Armband™. Instruments such as the SenseWear Pro Armband™ are comparatively more expensive ($950) and require technical knowledge for computer-based data entry and interpretation. In contract, the PAI costs approximately $35.00, is simple to understand and easy to use. The current investigation, while preliminary, suggests that the PAI is an affordable public health tool that can assist lay individuals in estimating kcal expenditure for varying walking intensities.

The ability to accurately estimate kcal expenditure for locomotor activities is an important application of the PAI. Many public health recommendations and weight loss interventions prescribe an exercise energy deficit. This prescription process is often difficult for lay individuals to comprehend. For example, current exercise recommendations suggest that to lose weight and to prevent weight regain, one should expend 300-500 kcal per day (Jakicic, 2001). Although valid, this recommendation is difficult for the general population to implement given the lack of understanding of the appropriate total physical activity load (i.e. volume and intensity) that is required to attain the target energy expenditure. The PAI appears to be a useful tool to better estimate kcal expenditure during walking, thus helping to achieve public health recommendations regarding physical activity participation.

The PAI may also serve as a guide to prescribe physical activity programs (volume and intensity) to promote health, reduce excess body weight and maintain ideal body weight long term. For example, the PAI could be used to augment pedometer based physical activity interventions such as the one conducted by Merom et al. (2007). Merom et al. used pedometers as a motivational strategy to increase physical activity in a community-based, nonclinical sample of 369 individuals. Subjects were randomized into three groups: a walking group, walking group with pedometers and a no-treatment control group. Self-report questionnaires indicated that the walking group with pedometers significantly increased physical activity and sports/recreation participation as compared to the other two groups (Merom et al., 2007). It is proposed that the effects of such interventions could be enhanced by using the PAI to measure relative exercise intensity and kcal expenditure.

In addition, the PAI can be used as a means to evaluate physical activity outcomes in public health, clinical, and/or rehabilitation settings. Self-report questionnaires, which are often used in these settings, do not always provide accurate measures of physical activity or kcal expenditure (Tudor-Locke, 2002). By using the proposed PAI, exercise professionals and clinicians may be better able to evaluate clients' current physical activity status and associated kcal expenditure.

5.7 RECOMMENDATIONS

Findings of the present investigation provide the basis for several avenues of future research.

1. Only one type of commercially available pedometer was used limiting generalizability of the findings to the model employed in this study. Future investigations should examine a range of pedometer models and anatomical placements of the instruments.
2. The current investigation validated the PAI for recreationally active females between the ages of 18 and 24 years. Future research should include children, adolescents, male adults, older adults, sedentary/overweight/obese individuals, and/or athletes, in order to generalize results to more diversified segments of the population.
3. Inter-individual differences in gait cycle and stride length may have effected the PAI measurements, especially during the very slow (4.02 $km \cdot hr^{-1}$) and very fast (7.24 $km \cdot hr^{-1}$) treadmill walking speeds. To account for variations in stride length, future research should factor in its effect when using the PAI to predict kcal expenditure for various locomotor intensities.
4. The current investigation examined 32 young, female adults. Using a larger sample size will provide a higher statistical power, strengthening generalization of the regression models.

5. The current investigation used three treadmill bouts approximating low, moderate and high walking intensities. Using different locomotor modes (i.e. running, jumping, hopping, sliding) and intensities for longer durations (i.e. 30 min) will result in kcal prediction equations that are more generalizable to physical activities typical of free living environments.

5.8 CONCLUSION

Several new physical activity intervention strategies have been developed to address the increase of obesity and physical inactivity among adult Americans. A number of these interventions use pedometer step counts to promote physical activity adoption and adherence, as well as to track intervention outcomes. The present investigation focused on a proposed method to enhance the information provided by pedometers in assessing total physical activity load (i.e. volume x intensity). Specifically, the present investigation validated a Physical Activity Index (PAI) to measure the total activity load and associated kcal expenditure of young women performing varying walking intensities. For purposes of this investigation, the PAI was calculated as the product of pedometer step count and rating of perceived exertion (RPE) for each of three treadmill walking intensities. The PAI score was then used as the predictor variable in a model that estimated kcal expenditure for various walking intensities.

It was the purpose of the present investigation to develop and validate a statistical model that used the PAI to estimate kcal expenditure during treadmill walking. Concurrent validation was evidenced by strong, statistically significant correlations between the PAI and both VO_2 and HR responses to a range of treadmill walking intensities. In addition, the PAI provided a valid estimate of kcal expenditure for young women performing treadmill walking. The following statistical model (Model III) was used to estimate kcal expenditure from PAI scores.

Predicted kcal = 28.056 + 0.006 (PAI score) $\quad$ **$p < 0.05$, SEE = 17.34, $r = 0.80$, $r^2 = 0.64$**

The PAI was most accurate at estimating kcal expenditure at moderate walking intensities and slightly less accurate at estimating kcal expenditure at low and high walking intensities.

The SenseWear Pro Armband was also used to estimate kcal expenditure during treadmill exercise. The kcal expenditure estimated by the Armband method was significantly higher than the measured kcal expenditure at the low walking intensity and significantly lower than the measured kcal expenditure at moderate and high walking intensities. Overall, the Armband was found to be less accurate in estimating kcal expenditure than the PAI when examined over treadmill walking bouts that ranged from low to high intensities.

With continued investigation to broaden subject demographics and activity modes, it is proposed that the PAI can be used in the public health setting as a tool to estimate kcal expenditure for a range of locomotor activities. The PAI is a simple and inexpensive means to predict kcal expenditure during varying intensities of walking in young adult women and could potentially serve as a physical activity indicator for weight loss and/or exercise interventions. It is proposed that with further development and validation, the PAI can be used in educational, public health, clinical, and/or rehabilitation settings to monitor physical activity patterns and outcomes.

APPENDIX A

RISK FACTORS AND STRATIFICATION

RISK FACTORS

Positive Risk Factors	**Defining Criteria**
Family History	Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in mother or other female first-degree relative
Cigarette Smoking	Current cigarette smoker or those who quit within the previous 6 months
Hypertension	Systolic blood pressure ≥140 mmHg or diastolic ≥90 mmHg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication
Dyslipidemia	Low-density lipoprotein (LDL) cholesterol >130 $mg \cdot dl^{-1}$ or high-density lipoprotein (HDL) <40 $mg \cdot dl^{-1}$, or on lipid-lowering medication. If total serum cholesterol is all that is available use >200 $mg \cdot dl^{-1}$ rather than low-density lipoprotein (LDL) >130 $mg \cdot dl^{-1}$
Impaired Fasting glucose	Fasting blood glucose ≥100 $mg \cdot dl^{-1}$ confirmed by measurement on at least two separate occasions
Obesity	Body mass index >30 $kg \cdot m^{-2}$ OR waist girth >102cm for men and >88cm for women OR waist/hip ration: ≥0.95 for men and ≥0.86 for women
Sedentary Lifestyle	Persons not participating in a regular exercise program or not meeting the minimal physical activity recommendations from the U.S. Surgeon General's Report
Negative Risk Factor	**Defining Criteria**
High-Serum HDL cholesterol	>60 $mg \cdot dl^{-1}$

RISK STRATIFICATION

Level of Risk	**Defining Criteria**
Low	Men <45 years of age and women <55 years of age who are asymptomatic and meet no more than one risk factor threshold from above table
Moderate	Men >45 years and women >55 years OR those who meet the threshold for two or more risk factors from above table
High	Individuals with one or more signs and symptoms OR known cardiovascular, pulmonary or metabolic disease

APPENDIX B

MEDICAL HISTORY FORM

MEDICAL HISTORY FORM

Assess your health needs by marking all *true* statements.

History

You have had:

-- a heart attack

-- heart surgery

-- cardiac catheterization

-- coronary angioplasty (PTCA)

-- pacemaker/implantable cardiac defibrillator/rhythm disturbance

-- heart valve disease

-- heart failure

-- heart transplantation

-- congenital heart disease

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a ***medically qualified staff.***

Symptoms

-- You experience chest discomfort with exertion.

-- You experience unreasonable breathlessness.

-- You experience dizziness, fainting, blackouts.

Other health issues:

-- You have musculoskeletal problems.

-- You have concerns about the safety of exercise.

-- You take prescription medication(s).

-- You are pregnant.

-- You take heart medications.

Cardiovascular risk factors

-- You are a man older than 45 years.

-- You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.

-- You smoke.

-- Your blood pressure is greater than 140/90.

-- You don't know your blood pressure.

-- You take blood pressure medication.

-- Your blood cholesterol level is >240 mg/dL.

-- You don't know your cholesterol level.

-- You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).

-- You are diabetic or take medicine to control your blood sugar.

-- You are physically inactive (i.e., you get less than 30 minutes of physical activity on at least 3 days per week).

-- You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a ***professionally qualified exercise staff*** *to guide your exercise program.*

-- None of the above is true.

You should be able to exercise safely without consulting your healthcare provider in almost any facility that meets your exercise program needs.

APPENDIX C

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

PAR-Q & YOU

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

1. **Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
2. **Do you feel pain in your chest when you do physical activity?**
3. **In the past month, have you had chest pain when you were not doing physical activity?**
4. **Do you lose your balance because of dizziness or do you ever lose consciousness?**
5. **Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
6. **Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
7. **Do you know of any other reason why you should not do physical activity?**

YES to one or more questions
If you answered

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

➔

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____

DATE____

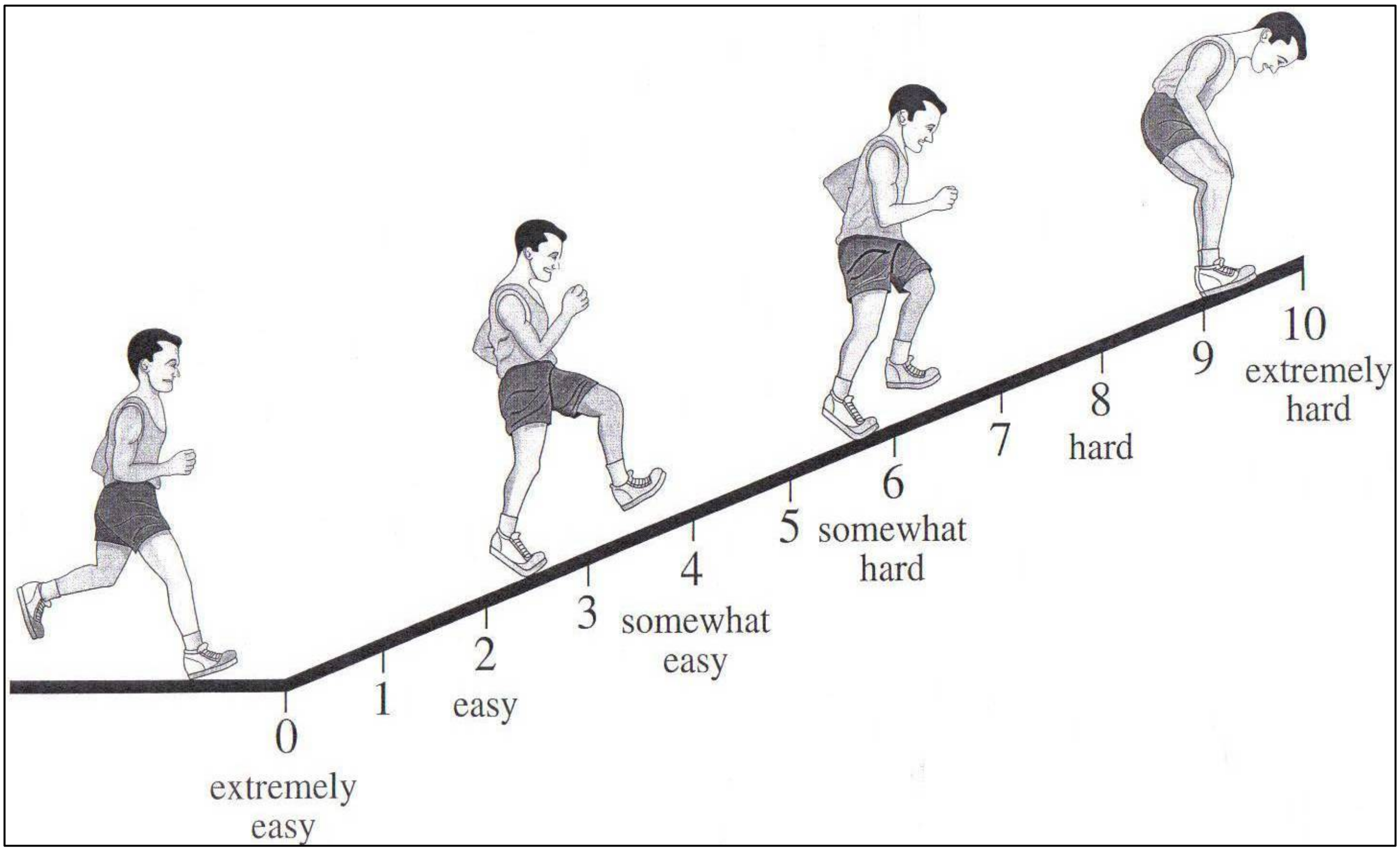
SIGNATURE OF PARENT ____

WITNESS or GUARDIAN (for participants under the age of majority) ____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

APPENDIX D

ADULT OMNI WALK/RUN SCALE



APPENDIX E

OMNI RPE SCALING INSTRUCTIONS

Definition of RPE:

We define physical exertion as the intensity of effort, strain, discomfort or fatigue that you feel during exercise.

Instructions:

We would like you walk on a treadmill. Please use the numbers on this scale to tell us how your body feels when you are walking. Please look at the person at the bottom of the hill who is just starting to walk (*point to the left-hand picture*). If you feel like this person when you are walking, the exertion will be *Extremely Easy*. In this case, your rating should be the number 0. Now look at the person who is exhausted at the top of the hill (*point to the right-hand picture*). If you feel like this person when walking, the exertion will be *Extremely Hard*. In this case, your rating should be the number 10. If you feel somewhere between *Extremely Easy* (0) and *Extremely Hard* (10), then give a number between 0 and 10.

We will ask you to point to the number that tells how your whole body feels. There is no right or wrong number. Use both the pictures and the words to help you select a number. Use any of the numbers to tell how you feel when you are walking.

Ask the subject the following questions and instruct them to point to the appropriate scale number.

1. How do you feel right now?
2. When you are walking up a hill, how do you feel?
3. When you exercised as hard as you can ever remember, how did you feel?

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