ESTIMATING CALORIC EXPENDITURE USING THE PHYSICAL ACTIVITY INDEX (PAI) IN CHILDREN AND ADOLESCENTS PERFORMING A MULTISTAGE MAXIMAL EXERCISE TEST

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PURPOSE: The primary purposes of this investigation were (a) to examine the validity of the PAI, (b) to develop a statistical model to predict cumulative Kcal expenditure using PAI as the predictor variable and (c) to develop a statistical model to predict total Kcal expenditure using PAI_{total} and selected physiological and behavioral measures as the predictor variables for children and adolescents performing load incremented maximal treadmill exercise. The secondary purpose of the study was to develop a prediction model to estimate total Kcal expenditure using the PAI (session) alone and in combination with selected physiological measures as the predictor variables. **METHODS:** Eighty-four children and adolescents (12.5±2.4 yrs) performed a maximal Bruce treadmill (TM) protocol. During TM, heart rate (HR), oxygen consumption (VO_2), rating of perceived exertion (RPE-overall), pedometer step count, and Kcal expenditure were measured. Post-TM, RPE-session was obtained and a physical activity questionnaire administered. The PAI, PAI_{total}, and PAI (session) were calculated as:

PAI = Cumulative step count x RPE-overall

PAI_{total} = Total step count x RPE-overall at test termination

PAI (session) = Total step count x RPE-session

RESULTS: Multiple regression analyses revealed a strong, positive relation between the PAI score and VO_2 in $L.min^{-1}$($r=0.607$, $p<0.05$), VO2 in $mL.kg^{-1}.min^{-1}$ ($r=0.725$, $p<0.05$) and HR in

beats.min^{-1} (r=0.755, p<0.05). These findings established a high level of concurrent validity for the PAI. The following models to predict Kcal expenditure were developed:

Model I : Cumulative Kcal = 21.632 + 0.006(PAI) p<0.05, SEE=17.59, r=0.74, r^2=0.54.

Model II : Total Kcal = -11.59+0.002(PAI_{total})+27.245(VO_2max) p<0.05, SEE=15.37, r=0.86, r^2=0.739.

Model V : Total Kcal = 38.6 + 0.004(PAIsession), p<0.05, SEE=24.23, r=0.36, r^2=0.13.

Model VI : Total Kcal = -64.759+26.998(VO_2max)+0.305(HRmax)+0.001 (PAIsession) p<0.05, SEE=10.46, r = 0.918 , r^2 = 0.842.

In comparison to the PAI (session), PAI was a stronger predictor of Kcal expenditure during a load incremented treadmill protocol in a sample of children and adolescents. **CONCLUSIONS:** The PAI has public health implications, provides an easy tool to estimate total physical activity load (i.e. volume x intensity) and predicts Kcal expenditure in children and adolescents performing standard treadmill exercise protocols. Generalizability of findings is limited to healthy children and adolescents performing load incremented maximal treadmill exercise.

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1.0 INTRODUCTION

The purpose of this investigation was to develop and validate a Physical Activity Index (PAI) to estimate energy expenditure of children performing a load incremented maximal treadmill protocol. The PAI is a new measurement tool that includes the intensity and volume dimensions of physical activity (176). The volume component of the index is measured using pedometer step counts while the relative exercise intensity is measured as a rating of perceived exertion (RPE). The index was first described by Weary et al., in 2006 for use with female and male adults:

PAI = Volume (total number of steps) x Intensity (RPE) (176).

The concurrent validity of the PAI was established using oxygen uptake (VO_2; r=0.91) and heart rate (HR; r=0.85) as criterion variables. It was concluded that PAI provides a valid estimate of Kilocalorie (Kcal) expenditure for walking exercise (r=0.86) (178).

The current study employed data derived from a primary investigation titled “Childhood metabolic markers of adult morbidity in blacks”. The purpose of the primary study was to compare metabolic differences between white and black children and to examine mechanisms that may predispose black children to metabolic disorders and associated clinical abnormalities during adulthood. The study was funded by the National Institutes of Health and conducted at Children’s Hospital of Pittsburgh (Principal Investigator: Dr. Silva Arslanian).

The prevalence of obesity is rising across all age groups in the United States. The National Health and Nutrition Examination Survey (NHANES) 2009-2010 reported that more than one-third of the US adult population was obese. The NHANES report indicated that from 1988 through 2010 the prevalence of obesity among men increased from 20.2% to 35.5% and for women 25.4 % to 35.8% (47,120,121). Similar trends have been observed for American children and adolescents. In the 1971-74 NHANES data, the prevalence of obesity among 2-19 yr old was 5%, increasing to 16.9% by 2009-2010. In the span of 4 decades the prevalence of obesity in children/adolescents increased by 238% (118,120). Various studies worldwide have reported similar obesity trends in pediatric populations (78,103,104). This poses a significant health concern, as excess body weight is associated with various metabolic disorders and other chronic diseases (185). The etiology of childhood obesity is unclear, but high dietary caloric intake and physical inactivity play pivotal roles in weight gain (11). Physical activity in conjunction with diet, rather than diet alone, is much more effective in promoting weight loss (35). Irrespective of weight loss, participation in physical activity has health benefits. Regular physical activity also lowers all cause-mortality in adults (21).

In order to derive health benefits, it is recommended that children and adolescents accumulate at least 60 minutes of moderate to vigorous intensity physical activity daily (162). Thus, valid assessment of an individual's physical activity is crucial in determining whether these recommendations are achieved. The commonly used instruments for physical activity assessment are self-report questionnaires and diaries. Self-reported physical activity has limitations including difficulty to recall accurately (5,146), and discrepancy in understanding certain words in a questionnaire (183). Nevertheless, questionnaire methodology is widely used in adult populations to survey physical activity behavior. However, children often lack the cognitive ability to recall physical activity level accurately. Thus the validity of self-reported physical activity level in this population is subject to considerable measurement error (13).

An alternative method of physical activity assessment is objective monitoring using motion sensors i.e. accelerometers and pedometers. Accelerometers “use piezoelectric transducers and microprocessors that convert recorded accelerations to a quantifiable digital signal referred to as counts” (155). Accelerometers are based on the rationale that the muscular forces required for movement are directly proportional to acceleration, the measure of which can be used to assess the total amount of physical activity and associated energy expenditure (54). Accelerometers can measure movement in one plane (uniaxial accelerometers), two planes (biaxial accelerometers), and three planes (triaxial accelerometers). In contrast, pedometers measure total step count by detecting only vertical acceleration of the hip during a walking movement. Both types of instruments (i.e. accelerometers and pedometers) provide objective monitoring of physical activity. Of importance to the present investigation is that the step counts measured by accelerometers and pedometers can be used to estimate energy expenditure during physical activity (50).

Both pedometers and accelerometers are classified as motion sensors. However, a pedometer measures acceleration or deceleration in one direction, whereas an accelerometer can employ uniaxial, biaxial, and triaxial architecture. Pedometers typically provide only total step count, whereas accelerometers provide a more detailed output by utilizing experimentally validated algorithms to estimate energy expenditure. Compared to accelerometers, pedometers are low cost and require less user expertise. Pedometer measures of physical activity correlate highly with accelerometer measures (15,84,97), direct observation (15,84), and physical activity self-report (15,97). Since pedometers provide objective monitoring and instant feedback regarding physical activity behavior, they facilitate goal setting, and enhance motivation for participation (171).

In general, pedometers are valid and reliable tools to measure distance traveled and total steps taken during many weight bearing physical activities. However, these step count measures do not differentiate between varying intensities of physical activity. Since a pedometer is sensitive to vertical movement but fails to account for the activities' intensity, it assumes that the total energy expenditure is similar for walking and running, provided the total steps are equal. Various studies show the correlation between pedometer outputs (measured step counts) and energy expenditure (measured by respiratory metabolism and/or estimated by statistical modeling) is between r=0.46 to 0.88 (171). The doubly labeled water technique has also been used to validate energy expenditure estimated from pedometer step counts. The doubly labeled water technique is considered one of the gold standards in estimating total energy expenditure over a defined period of time; usually 12 or 24 hours (110). One study reported a significant correlation (r=0.61) between pedometer counts and measured energy expenditure over a 48 hour period using a doubly labeled water technique (59). However, other studies failed to demonstrate similar results (48,98).

A pedometer measures the volume component of physical activity by recording total number of steps in a defined unit of time. In adults the general recommendation for positive health outcomes is to accumulate 10,000 steps.day^{-1} as measured by a pedometer (67). Depending on the walking speed and body weight, this physical activity volume is approximately equivalent to an energy expenditure of 300-400 Kcal.day^{-1} (67). In children and adolescents 12,000 steps.day^{-1} are recommended to achieve health benefits (31). These step recommendations are closely aligned with the American College of Sports Medicine (ACSM) physical activity guidelines for children and adolescents (31). However, it is important to note that the recommended number of steps.day^{-1} reflects the volume of the physical activity but does not take movement intensity into consideration.

The ACSM recommends participation in moderate to vigorous intensity physical activity for at least 60 minutes almost daily to promote health in children and adolescents (162). Moderate intensity exercise is equivalent to 3 METs (Metabolic Equivalent Tasks) energy expenditure while vigorous intensity exercise requires greater than 6 METs energy expenditure (162).The literature supports that most moderate intensity physical activities are equivalent to 3METs energy expenditure in healthy young and middle aged adults. But this may not be true of other populations. The same physical activity can require different relative metabolic rates between individuals depending on their aerobic fitness levels (100). For example, two people (A and B) have different maximal aerobic power. Individual "A" has a high level of aerobic fitness and "B" has a low aerobic fitness level. According to ACSM guidelines both individuals should participate in a moderate (i.e.3 METs) intensity exercise program. For "A", a 3 METs activity could require a relative metabolic intensity that is too low to promote significant cardiovascular adaptations. In contrast, for individual "B", the 3 METs level may require a relative intensity that is too high to be sustained for the entire exercise conditioning session. As such, a measure of the relative exercise intensity is needed to individualize an aerobic exercise prescription. This exercise prescription problem arises because ACSM guidelines are based on absolute energy expenditure values for a group and do not consider the effect of inter-individual differences in aerobic fitness on the relative energy expenditure. Therefore, it is suggested that relative intensity should be used in exercise prescription, as it will be more reflective of individual differences in aerobic fitness.

An accurate and comparatively easy method to estimate relative exercise intensity is by rating the level of perceived exertion. The perception of exertion is defined as the subjective intensity of effort, strain, discomfort, and/ or fatigue that is experienced during physical exercise. The concept of and methods to measure exertional perceptions were developed and validated by Gunnar Borg, a Swedish experimental psychologist (22,116). The original RPE scale (6-20 rating) was developed by Borg in the late 1950's and early 1960's. Ratings of perceived exertion can also be measured using a numerical/pictorial metric such as the 0-10 category OMNI Walk/Run Scale (116).

It has been established that RPE provides an estimate of the relative exercise intensity and highly correlates with physiological variables such as HR and VO_2 measured during exercise (137). An RPE provides a valid measure of the relative intensity for different exercise modes (65,135,137,138) that employ both progressive and intermittent protocols. These findings hold for both females and males who vary in age and aerobic fitness (56). Therefore, a RPE has public health implications for physical activity behavior as it can be used to report relative exercise intensity in physical activity questionnaires (150) and to self-regulate prescribed exercise intensity (149).

An RPE can be expressed as an undifferentiated measurement for the overall body (RPE-overall) or it can be differentiated separately for limbs (i.e. RPE-legs) and chest/breathing (i.e. RPE-chest). The intensity of the differentiated RPE is mediated by energy producing and contractile properties of skeletal muscle in limbs and chest, whereas the undifferentiated RPE represents a global subjective sensation of exertion for the total body. For the current study, undifferentiated RPE (RPE-overall) was used as an indicator of relative intensity during treadmill walking and in the development of a Kcal prediction model based on the PAI.

There are various ways of measuring RPE. An in-test (i.e. momentary) RPE can be measured on a moment-to-moment basis. In addition, a RPE-session can be obtained immediately following completion of an exercise task (50). The RPE-session provides a measure of the global exertion experienced during the just completed task. Several previous investigations conclude that the RPE-session provides a psychophysiological estimate of the average exertion experienced during either a steady or non-steady state exercise session (50,165,175). RPE-session was originally used to monitor monotony and intensity of training in athletes. Recent research has focused on the use of RPE-session in non-athletic populations to monitor the relative intensity of a physical activity bout. RPE-session is a valid method to monitor global exertion experienced during both aerobic and resistance exercise (165). The current study used RPE-session as a measure of the relative intensity of the entire exercise bout and in calculation of the PAI (session) to estimate total Kcal expenditure for the entire exercise bout.

An effective exercise program consists of two key components, i.e. intensity (preferably relative) and volume. Therefore, when evaluating the effectiveness of an exercise program it is essential to consider these two components for a given performance mode. The PAI is a new measurement tool that encompasses both of these key dimensions of physical activity programming. Weary et al. (176,178) have undertaken two separate investigations pertaining to the development and validation of the PAI. The most recent of these studies examined the development and validation of the PAI to estimate total Kcal expenditure during three different walking intensities. The three walking intensities corresponded to 30% (i.e. low), 55% (i.e. moderate), and 80% (i.e. high) of maximal oxygen uptake (VO_2max). The PAI score correlated strongly ($p<0.05$) with HR ($r=0.85$) and VO_2 ($r=0.91$). The findings indicated that during sub-maximal exercise, the PAI is a better predictor of Kcal expenditure ($r=0.85$) (178) than when pedometer counts (r=0.68) (171) are used separately as predictor variables. The Kcal prediction model was more accurate for moderate and high walking intensity than for low walking intensity (177).

The studies (176,178) by Weary et al., examined the validity of the PAI in college age recreationally active males and females. There is one published research investigation that examined the relation between PAI score and Sensewear armband derived energy expenditure among 12 year old children. The study reported low to moderate correlation coefficients (r=0.16-0.44) between the PAI scores and armband measured energy expenditure (93). This study didn't report the validity of the PAI for use with children.

1.1 SIGNIFICANCE OF THE STUDY

It was proposed that the PAI has public health implications, provides an easy tool to estimate total physical activity load (i.e. volume x intensity) and its associated Kcal expenditure during load incremented maximal treadmill exercise in children and adolescents. It is further proposed that the PAI can be an effective component of exercise programming in obesity prevention and treatment. The PAI can also act as motivation tool for maintaining a physically active lifestyle in children as it provides both objective and subjective monitoring of physical activity levels.

1.2 STATEMENT OF THE PROBLEM

The purposes of this study were:

1. To examine the validity of the PAI using measured VO_2 and HR as criterion variables in 8-17yr old female and male children and adolescents performing a load incremented maximal treadmill protocol.
2. To develop a statistical model to estimate cumulative Kcal expenditure using the PAI as a predictor variable for children and adolescents (8-17 yr) performing load incremented treadmill exercise.
3. To develop a statistical prediction model to estimate total Kcal expenditure of children and adolescents (8 to 17 yr) performing a load incremented maximal treadmill protocol, where total PAI score (PAI_{total}), age, height, weight, body mass index (BMI), BMI percentile, maximal heart rate (HRmax), VO_2max, maximal respiratory exchange ratio (RERmax), leisure time physical activity and sedentary behavior were potential predictor variables.
4. To develop a statistical model to estimate total Kcal using the PAI (session)as a predictor variable for children and adolescents (8-17 yr) performing load incremented treadmill exercise.
5. To develop a statistical model to estimate total Kcal using the PAI (session), HRmax, and VO_2max as predictor variables for children and adolescents (8-17 yr) performing load incremented treadmill exercise.

1.3 RESEARCH HYPOTHESES

1. It was hypothesized that the PAI would demonstrate significant positive correlations with $VO_2$and HR responses for 8-17 yr old female and male children and adolescents performing a load incremental maximal treadmill protocol.
2. It was hypothesized that a statistical model using PAI as a predictor variable would explain significant variance in cumulative Kcal expenditure for 8-17 yr old female and male children and adolescents performing a load incremented maximal treadmill protocol.
3. It was hypothesized that a statistical model using PAI_{total}, age, height, weight, BMI, BMI percentile, HRmax, VO_2max, RERmax, leisure time physical activity and sedentary behavior as predictor variables would explain significant variance in total Kcal expenditure during a load incremented maximal treadmill protocol.
4. It was hypothesized that a statistical model using PAI (session) as a predictor variable would explain significant variance in total Kcal during a load incremented maximal treadmill protocol.
5. It was hypothesized that a statistical model using the PAI (session), HRmax, and VO_2max as predictor variables would explain significant variance in total Kcal expenditure during a load incremented maximal treadmill protocol.

2.0 LITERATURE REVIEW

The primary purposes of this investigation were (a) to examine the validity of the PAI and (b) to develop a statistical model to predict cumulative Kcal expenditure using PAI as the predictor variable and (c) to develop a statistical model to predict total Kcal expenditure using PAI_{total} and selected physiological and behavioral variables as the predictor variables for children and adolescents performing load incremented maximal treadmill exercise. The secondary purpose of the study was to develop a prediction model to estimate total Kcal expenditure using the PAI (session) alone and in combination with selected physiological variables as the predictor variables.

2.1 PHYSICAL ACTIVITY INDEX (PAI)

An effective exercise prescription consists of two key components, i.e. intensity (preferably relative) and volume. Therefore, when prescribing an exercise program it is essential to consider these two components. The PAI is a new measurement tool that encompasses both of these dimensions of physical activity programming. This index was introduced by Weary et al., in 2006:

$$\text{PAI} = \text{Volume (total number of steps)} \times \text{Intensity (RPE)} \qquad (176)$$

The volume is measured by pedometer step counts and relative intensity is measured by RPE. Pedometer step counts alone do not explain a large amount of variance in Kcal expenditure associated with physical activity such as walking and running. Therefore, it was proposed by Weary et al. that the inclusion of RPE in a statistical model would make the energy expenditure prediction more robust.

There are three published studies pertaining to the PAI (93,176,178). The preliminary study was conducted on sixteen recreationally active college age (23 yr) male (n=7) and female (n=9) subjects. The study focused on the development of the PAI using measures of RPE-overall and pedometer step counts. Measurements were obtained separately for three different intermittent treadmill exercise bouts. Each bout was 5 minutes in duration and consisted of the following treadmill 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. Each bout was separated by a five minute rest period and presented in counterbalanced order. The exercise bouts were equivalent to 30%, 55%, and 80% VO_2max as determined for individual subjects. The study reported a positive correlation of r=0.69 between the PAI and Kcal expenditure when responses were examined across the three relative exercise intensities (176).

The second study examined the development and validity of the PAI in estimating total Kcal expenditure for three different submaximal treadmill intensities. The study employed thirty two recreationally active college-aged (20 yr) females. The experimental protocol employed three counterbalanced intermittent submaximal 10 minute exercise bouts each consisting of the following speeds and grades: (a) low intensity (4.02 $km.hr^{-1}$ at 0% grade), (b) moderate intensity (5.63 $km.hr^{-1}$ at 2.5% grade), and (c) high intensity (7.24 $km.hr^{-1}$ at 5% grade). The following variables were measured during each exercise bout: VO_2, RPE, and pedometer step count. The caloric expenditure was calculated from respiratory-metabolic measures using RER adjustment to account for differential contributions of fat and carbohydrate oxidation. The concurrent validity of the PAI was established using VO_2(r=0.91) and HR (r=0.85) as criterion variables. The Kcal expenditure was estimated from a regression model that employed PAI as the predictor variable:

Predicted Kcal = 27.152 + 0.007 (PAI score) $p < 0.05$, SEE = 14.04, r = 0.86, $r^2 = 0.74$ (178)

The study reported that during sub-maximal exercise, Kcal expenditure predicted using the PAI correlated significantly (r=0.86, p<0.05) with energy expenditure derived from indirect calorimetry (178). This correlation coefficient was much higher than observed between pedometer estimated Kcal expenditure and Kcal expenditure (r=0.68) determined via indirect calorimetry (171). The model using the PAI to predict Kcal expenditure was validated against directly measured Kcal expenditure using respiratory-metabolic procedures. Weary et al. further reported that at lower exercise intensity, PAI over-predicted (p<0.05) Kcal expenditure. The accuracy of the PAI model in predicting Kcal expenditure was comparatively greater for moderate and higher intensities than for the lower intensity (178). The difference between predicted and measured Kcal expenditure may be attributed to varying levels of accuracy of pedometers at different walking speeds, plus individual differences in gait cycles and stride length (34). It was concluded that a PAI based model can accurately estimate Kcal expenditure in young women performing a moderate intensity treadmill exercise bout (178).

The third study involving the PAI employed 54 children (12±0.86 years). During physical education classes, the PAI was determined and energy expenditure was estimated using Sensewear Pro armbands. The correlation coefficient for the relation between the PAI scores and armband determined energy expenditure were r=0.16 to 0.44 across the various measurement time points. This study concluded that during physical education classes, PAI may be inadequate in measuring energy expenditure among children (93).

2.2 OBESITY PREVALENCE

2.2.1 Obesity prevalence among adults

Over the last few decades there has been an exponential increase in the prevalence of overweight and obesity among the adult population in the United States. Data from the NHANES corroborates this trend beginning in 1960. NHANES data demonstrated that from 1960 to 1980 the increase (13.4% to 15%) in obesity levels in the United States was minimal. However, between 1980 and 2010, the prevalence of obesity increased from 15% to 35.7% among U.S adults. NHANES 2009-2010 reported that more than one-third of the United States adult population was obese. The NHANES data indicate that from 1988 through 2010 the prevalence of obesity among men increased from 20.2% to 35.5% and for women from 25.4 % to 35.8%. (47,120,121).

Similar trends are also observed worldwide. Since 1980, prevalence of obesity has doubled worldwide. The World Health Organization (WHO) reported that in 2008 approximately 1.5 billion adults were overweight, and 500 million were obese worldwide. It has been projected that if current trends continue, by 2015 2.3 billion adults worldwide will be overweight and approximately 700 million adults will be obese. (180).

One of the landmark studies regarding the global prevalence of obesity among adults (35-64 yr old) was undertaken by the WHO. This study was called the Multinational **MONI**toring of trends and determinants in **CA**rdiovascular disease (MONICA) project. The MONICA study collected data for almost a decade (1980 through 1994) across 48 populations representing South- East Asia, Africa, Western Pacific, Europe, Eastern Mediterranean, North America, and South America. The study concluded that obesity is a global epidemic, and the situation is worsening with the passage of time.

2.2.2 Obesity prevalence among children and adolescents

The prevalence of obesity is on the rise in the United States across all adult age groups. Similar trends have also been observed for American children and adolescents. In the 1971-74 NHANES report, the prevalence of obesity among 2-19 yr old was 5%. In this same age group obesity increased to 16.9% by 2009-2010. In the span of 4 decades the prevalence of obesity in children/adolescents increased by 238% (118,120).

The results of the NHANES report from 1988 through 2010 indicate that the prevalence of obesity among boys increased from 11.3% to 18.6% and for girls from 9.7 % to 15% during this period. This indicates an increase in obesity prevalence by 64% for boys and 54.6% for girls from 1988 through 2010 (118,120).

NHANES age specific data show that for children 6-11 years old, obesity prevalence increased by 350% (4% to 18%) between 1971 and 2010. During the same time period, obesity increased by 142% (5% to 12.1%) in preschool aged children and by 201.6% (6.1% to 18.4%) in adolescents. According to recent data from NHANES 2010, the prevalence of obesity was higher among adolescents than any other age group in the pediatric population (118,120).

Various studies worldwide have indicated similar obesity/overweight trends in pediatric populations (78.103,104). According to the International Obesity Task Force (IOTF), worldwide there are approximately 200 million school aged children who were overweight and among these 40-50 million are obese. Obesity among children and adolescents is increasing at an alarming rate and it is of concern not just in developed countries, but also in developing countries.

Lobstein et al. (102) reported that approximately 10% of children 5–17 years old worldwide were overweight and that 2–3% was obese (102). Among children, prevalence rates vary considerably between different geographical regions and countries, from <5% in Africa and parts of Asia to >20% in Europe and >30% in the Americas and some countries in the Middle East (76).

A recent study surveyed the prevalence of overweight and obesity among preschool children from 144 countries (36). The study revealed that the global prevalence of overweight and obesity among 1-5 year old children in 1990 was 4.2%. In the same age group, this prevalence increased to 6.7% by 2010. It is estimated that these trends will continue and by 2020 obesity prevalence will reach 9.1% of the pediatric population worldwide. For the last two decades, similar trends of increasing obesity were observed in developing (3.7% to 6.1%) as well as developed countries (7.9% to 11.7%). Using 2010 data, the obesity prevalence is 6.1% lower in developing countries than in developed countries, but the absolute number of affected children (34.7 million) is higher in developing countries. Irrespective of geographical location, the increase in overweight and obesity is a worldwide health problem. Between 1990 and 2010, the prevalence of overweight and obesity increased by 59.5% globally. By geographic region, overweight and obesity in children increased 112.5% in Africa, 53.1% in Asia, and 1.5% in Latin America and Caribbean countries (36). Kosti et al. estimated that between 1990 and 2010, the prevalence of overweight and obesity in school-aged children doubled. (87)

2.3 DEFINITION OF OBESITY FOR CHILDREN AND ADOLESCENTS

For children and adolescents, overweight and obesity are defined using age- and sex-specific nomograms for BMI. Children with BMI ($Kg.m^{-2}$) equal to or exceeding the age- and gender-specific 95th percentile are defined as obese. Those with BMI equal to or exceeding the 85th percentile – but below the 95th percentile – are defined as overweight. (7)

2.4 OBESITY ASSOCIATED DISORDERS

Excess body weight among children and adolescents is associated with various health disorders during adulthood, including cardiovascular disease, metabolic syndrome, type 2 diabetes, orthopedic disorders, and pulmonary diseases (123).Obesity during adolescence is also associated with an increased risk of mortality and lower life expectancy in adulthood (68). The Harvard longitudinal study involving a 55 year follow-up protocol, reported that all-cause mortality (including cardiovascular abnormalities) was higher among men who were overweight during adolescence (109). In addition, increased prevalence of overweight and obesity during childhood and adolescents was associated with comparatively greater all-cause mortality when the individual reached adult age (95,110)

2.4.1 Childhood obesity and adulthood obesity

The level of adiposity during childhood and adolescence is correlated with adult adiposity. The association gets stronger with increasing age in childhood (32,33). Numerous longitudinal studies have demonstrated strong association between childhood obesity and adulthood obesity (3,60,151,158). As early as 1960, Abraham and Norsdiek reported that 74% of males and 72% of females, who were obese during childhood, would remain obese in adulthood (4). Childhood obesity puts the pediatric population at increased risk for adulthood obesity. This poses a significant concern, as excess body weight is associated with various metabolic disorders and other chronic diseases that become significant health problems in adulthood (185).

2.4.2 Childhood obesity and health care cost

In the past few decades, an increase in adult health care cost has been associated with the increase morbidity risk of obesity among children and adolescents (73). The Harvard Growth study observed that the morbidity risk for chronic diseases was higher among men and women who were overweight in adolescence as compared to those who were lean (114). Must et al. demonstrated that irrespective of adult BMI, there is a positive correlation between adolescent obesity and long-term mortality and morbidity (114).

2.4.3 Childhood obesity and cardiovascular risk factors

Elevated insulin levels and decreased insulin sensitivity are associated with abnormally high body fatness (86). In comparison to leaner subjects, insulin resistance and elevated fasting insulin levels are more frequently observed in obese children (19,133). There is a positive linkage between adult insulin levels and childhood BMI (52,53,154). Being overweight during childhood and adolescence is linked to elevated LDL-cholesterol, total cholesterol, and triglycerides, and to low HDL-cholesterol levels in adulthood (25,132). Other cardiovascular risk factors such as hypertension (128,157), left ventricular hypertrophy (156), obstructive sleep apnea, and systemic inflammation (62) are also associated with childhood obesity. Thus, numerous studies report a positive association between childhood obesity and adult metabolic syndrome (112) and cardiovascular disease (20,94,126). It is proposed that the prevention and treatment of childhood and adolescent obesity can be instrumental in reducing cardiovascular disease prevalence throughout adulthood (51).

2.4.4 Childhood obesity and other comorbidities

Childhood obesity is also associated with psychosocial abnormalities. It is linked with depression, low self-esteem, poor body-image, and loneliness (10,68,71*)*. The comorbidities associated with childhood obesity are listed in Table 1.

Table 1. Comorbidities associated with childhood obesity

System	Comorbidity
Cardiovascular	High blood pressure
	Early onset of atherosclerosis
	Left ventricular hypertrophy
Endocrine	Insulin resistance
	Diabetes mellitus (NIDDM)
	Menstrual abnormalities
	Polycystic ovarian syndrome (PCOS)
Gastrointestinal	Gallstones
	Nonalcoholic steatohepatitis (NASH)
	Hepatic fibrosis
	Cirrhosis
Neurological	Pseudotumor cerebri
Orthopedic	Slipped capital femoral epiphysis
	Tibia Vara
	Osteoarthritis
Psychosocial	Obsessive concern about body image
	Expectation of rejection
	Progressive withdrawal
	Low self esteem
	Depression
Pulmonary	Increased bronchial hyperactivity
	Asthma exacerbation
	Obstructive sleep apnea
	Pickwickian syndrome
	Pulmonary embolism
Renal	Increased sensitivity to sodium
	Decreased natriuresis
	Proteinuria
	Focal segmental glomerulosclerosis (FSGS)

From Raj M, Kumar RK.Obesity in children and adolescents.*Indian Journal of Medical Research*.2010;132(5):601 p (129).

2.5 WEIGHT CONTROL AND BODY COMPOSITION

Diet restriction and physical activity are integral and important components of a weight control program. The caloric restriction alone can markedly decrease total body fat mass. However, weight control programs often result in a combined reduction in both fat mass and fat free mass; the later effect being an unwanted response to the intervention (8,72,186). However, physical activity without dietary Kcal restriction leads to an absolute level of weight loss that is much less than expected (107). The most successful weight loss strategy is to employ a combination of diet and exercise, as this type of intervention reduces excess fat mass while preserving lean mass. The combination of these two interventions creates a negative energy balance and aids in optimal weight loss (23,160,186,188). Combined exercise and dietary interventions also help in long term effective maintenance of weight loss (160,188). Similar results have been observed for pediatric samples involved in weight loss interventions (39,46,125). Thus, a successful weight management program includes dietary Kcal restriction and physical activity participation.

2.6 PHYSICAL ACTIVITY

In the following literature review the importance of physical activity as a component of a weight loss intervention is explained and discussed.

2.6.1 Physical activity recommendation

Physical activity refers to “any bodily movement produced by skeletal muscles that result in energy expenditure” (145). The earliest physical activity recommendation for children and youth was developed by the American College of Sports Medicine in 1988. The recommendation was to participate in at least 20 to 30 minutes of vigorous exercise on a daily basis. These physical activity guidelines were based on the available literature for adults, as there were limited published studies involving the pediatric population (8).

With passage of time and availability of more published information regarding the association between physical activity and health in the pediatric population, The United Kingdom Health Education Authority (1998) published their physical activity recommendation for children and youth. As per the recommendation, children and youth were encouraged to accumulate 60 minutes of moderate-to-vigorous intensity physical activity on a daily basis (69).

In 2005, the U.S. Centers for Disease Control and Prevention recommended that children and adolescents accumulate at least 60 minutes of moderate to vigorous intensity physical activity daily for health benefits. Aerobic exercise at either moderate or vigorous intensity should comprise most of this 60 minute period. Children and adolescents should participate in vigorous intensity exercise at least three times per week. The 60 minutes of physical activity should include muscle and bone strengthening activity at least 3 days per week. It is important that these activities are enjoyable, age appropriate and offer an array of exercise types (162).

2.6.2 Physical activity in children

The recent Youth Risk Behavior Surveillance (YRBS) reports that only 28.7% of children in the United States are meeting the recommended minimum of at least 60 minutes of physical activity 7 days per week. The attainment of recommended physical activity was higher among males (38.3%) than females (18.5%). In contrast, the prevalence of not participating in at least 60 minutes of physical activity on any day was higher among females (17.7%) than in males (10%). The data for children of both genders show that there is a decline in physical activity participation with increasing age. These findings from the YRBS are consistent with other studies of physical activity in children and adolescents (147,167).

In the last decade, there has been a nationwide decline in attendance of Physical Education classes among United States school children. The 1991-2011 YRBS report indicates that the students who attended daily Physical Education classes decreased from 41.6% to 31.5% during the observation period. This represents a decline of 24% in attendance of Physical Education classes between 1991 and 2011 (29).

2.6.3 Physical activity and health

2.6.3.1 Physical activity and health in adults

Physical activity has been associated with reduced all-cause mortality in adults. Paffenberger et al., (122) studied the association between reported physical activity and mortality risk in male Harvard Alumni. It was observed that death risk decreased with increased volume of reported physical activity (122). Similar results were observed in young and older adults. The subjects were followed from 1958 through 1985, with the longitudinal investigation concluding that physical activity has a protective effect on mortality risk (80).

A substantial number of studies have examined the relation between physical activity and cardiovascular disease. These studies have observed an inverse association between physical activity and cardiovascular disease risk (114). A 14-year follow-up study involving men and women reported that increased levels of physical activity reduced the risk for cardiovascular disease mortality (79). This protective effect of physical activity may be due to its salutary effects on cardiovascular disease risk factors i.e. lipid profile, blood pressure, blood clotting, and arrhythmias (61,66,99).

There are several studies linking physical activity to obesity prevalence in adults. Regular physical activity is associated with lower incidence of overweight and obesity (38,125). Greater levels of self-reported physical activity are highly related with favorable body composition (i.e. low-percent fat) and low BMI (30,38,55).Obesity itself is associated with high mortality and morbidity risk (57,73).

Physical inactivity is strongly associated with increased risk for diabetes (89,190). Numerous cross-sectional studies have demonstrated that a behavioral shift to sedentary lifestyle has increased the prevalence of diabetes (131,190). When non-diabetics were compared to their physically active cohorts, postprandial insulin and glucose values were higher for physically inactive subjects (90,106).Thus, it can be concluded that physical activity reduces the risk of all-cause mortality, cardiovascular disease, diabetes, and obesity among adults.

2.6.3.2 Physical activity and health in children

The relation between physical activity and health is well documented for adults, but the linkage is more difficult to establish for children. In children, there are no clinical disease outcome markers (stroke, heart attack) to assess the direct impact of poor physical activity habits on adverse cardiovascular events. Instead, the promotion of regular physical activity in children to achieve positive health outcomes is based on long-term outcomes. The relation between physical activity and health in young people in comparison to physical activity and health in adulthood is illustrated in Figure 1. It is proposed that participation in physical activity will serve as preventive medicine in later life. Thus more researchers are interested in examining the relation between physical activity and health status in children.

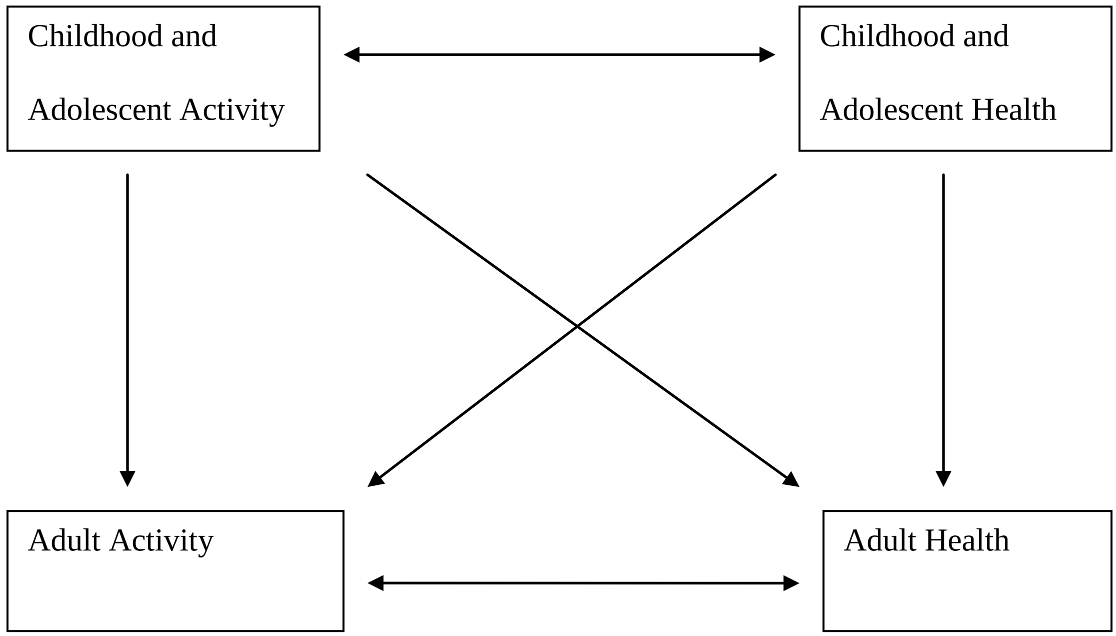

Figure 1.Relation between childhood and adolescent activity and health, with adult activity and health.

From Malina RM. Physical activity and fitness: pathways from childhood to adulthood. *American Journal of Human Biology*.2001;13(2):163 (105).

Cardiovascular disease

Atherosclerosis and coronary heart disease are uncommon in children. The relation between physical activity and coronary heart disease risk factors has been examined using such markers of cardiovascular disease as elevated blood pressure, elevated low-density lipoprotein (LDL), low levels of high-density lipoprotein (HDL), and high triglyceride. The atherosclerotic process begins early during childhood, and is strongly associated with incidence of cardiovascular disease later in life (159).

Various studies have reported an association between physical activity and blood lipid levels in children and adolescents (10,120,127,163). Kelley and Kelley (2007) performed a meta-analysis of training studies that observed the influence of physical activity on triglyceride, high density lipoprotein, low density lipoprotein, and total cholesterol. The duration of the interventions ranged between 5 to 16 weeks, and training frequency was between 3 to 5 times per week with total dosage of 20 to 60 minutes per session. There was a trend for lowered triglyceride levels and increased high density lipoprotein as a function of exercise training. The higher the training intensity the greater the salutary effect on low density lipoprotein levels, suggesting the role of physical activity intensity on normalizing lipids and lipoproteins (82).

Comparatively higher levels of physical activity are associated with lower systolic and diastolic blood pressure. However, these effects of physical activity are more substantial in hypertensive than normotensive children and adolescents (83,119). The Oslo Youth Study examined the association between physical activity levels and blood pressure in children and adolescents. In 1979, 1016 students (mean age 13 yr) were recruited for the study and their physical activity levels and baseline blood pressure were measured. The assessments were re-administered in 1981 (mean age 15yr), 1991 (mean age 25yr), 1999 (mean age 33yr), and 2006 (mean age 40yr). An inverse relation between physical activity levels and blood pressure was observed (92). These data confirmed the favorable impact of childhood physical activity levels on future hypertension risks.

Obesity

A number of cross-sectional and longitudinal studies have linked physical activity to the presence, treatment, and prevention of obesity in the pediatric population. These studies consistently associate regular physical activity with lower BMI (14,163). The Framingham Children's Study monitored 106 three-to-five-year-old children for diet, physical activity, and body composition. The subjects were followed longitudinally for 8 years with data collected annually. Body composition was assessed using height, weight, and skinfold thickness. Physical activity was objectively measured using a Caltrac accelerometer. The accelerometer data were collected biannually for consecutive 3 to 5 day periods during both weekdays and weekends. It was observed that a high level of measured physical activity was associated with low BMI and decreased accrual of body fat (111). Similar results were reported by the Oslo Youth Study, where participation in regular physical activity was a critical determinant for increased BMI over an 18-to 20-year interval (92). The study concluded that involvement in physical activity during childhood can have a protective effect in preventing overweight and possibly obesity during adulthood.

Diabetes

It is well documented that physical activity is crucial for management and treatment of diabetes. Physical activity is helpful in enhancing insulin sensitivity and decreasing abnormally elevated insulin levels. This preventive aspect of physical activity is important, as the incidence of diabetes in the United States is increasing not only in adults but also among young children and youth (27).

Lee et al. (96) investigated the relation between physical fitness, insulin sensitivity, insulin secretion and obesity. A total of 122 African American and White children and adolescents (8 to 17 years old) were recruited as subjects for the study. Body composition assessment was done using DEXA and physical fitness was measured via maximal treadmill testing. It was observed that low aerobic fitness was associated with decreased insulin sensitivity and increased total body and abdominal fat. Body composition (i.e. percent fat) had a strong influence on the relation between insulin sensitivity and physical fitness levels (96).

In children and adolescents, higher levels of physical activity have a favorable influence on cardiovascular disease risk factors such as, body composition, insulin levels, and insulin sensitivity. This suggests that higher physical activity levels may confer protection against obesity, lipid abnormalities, hypertension, and diabetes in later life.

2.7 PHYSICAL ACTIVITY MONITORS

In order to derive health benefits, it is recommended that children and adolescents accumulate at least 60 minutes of moderate to vigorous intensity physical activity daily (162). Thus, valid assessment of an individual's physical activity is crucial in determining whether these recommendations are achieved. The commonly used instruments for physical activity assessments are self-report questionnaires and diaries. However, self-reported physical activity using survey techniques has limitations including difficulty to recall accurately (5,146), and discrepancy in understanding certain words in the questionnaire (183). In addition, questions can be interpreted differently depending on cultural background and gender (88). Nevertheless, questionnaire methodology is widely used in adult populations to survey physical activity behavior. Children often lack the cognitive ability to recall physical activity level accurately. Thus the validity of self-reported physical activity level in the pediatric population is questionable (13).

An alternative method of physical activity assessment is objective monitoring using motion sensors i.e. accelerometers and pedometers. Accelerometers "use piezoelectric transducers and microprocessors that convert recorded accelerations to a quantifiable digital signal referred to as counts" (155). Accelerometer technology is based on the rationale that the muscle forces required for movement are directly proportional to acceleration. Measurement of body acceleration in turn allows assessment of the total amount of physical activity and associated energy expenditure (54). Accelerometers measure movement in one plane (uniaxial accelerometers), two planes (biaxial accelerometers), and three planes (triaxial accelerometers). Some accelerometers provide detailed output by utilizing scientifically validated algorithms that predict energy requirements of physical activity. As such, they typically require user expertise.

2.7.1 Pedometer

A pedometer employs a horizontal, spring-suspended lever arm that moves up and down with vertical accelerations of the hip (110). With each step, the lever arm makes an electrical contact, and one step or movement count is recorded. A pedometer measures total step count by detecting vertical acceleration of the hip during the movement, and thus provides objective monitoring of physical activity. A pedometer measures acceleration or deceleration in one direction, with the output typically being the total step count for a defined time period or distance. When body mass is entered into the pedometer microprocessor, Kcal expenditure is estimated by the manufacturer’s proprietary regression equation (110). Pedometers are low cost ($10-$40) and require comparatively less user expertise.

Pedometer measures of physical activity correlate highly with accelerometer measures (17,18,97), direct observation (84,148), and physical activity self-report (16,98). In addition pedometers provide instant feedback, objective monitoring, motivation for participation, and also facilitate physical activity goal setting. In general, pedometers are valid and reliable tools to measure distance traveled and total steps accumulated during many weight bearing physical activities.

The scope of usage of pedometers is not limited just to the measurement of step counts. Rooney et al., (142) reports that “The most significant benefit to wearing a pedometer may not be its ability to monitor the actual amount of activity in any given day, but rather to provide immediate feedback for participants, serving as a behavior modification tool (142)". Most pedometer studies have concentrated on the instrument's capability in measuring activity levels and predicting energy expenditure in adults. However, application of pedometer technology in promoting healthy behavior has not been studied extensively in children (37,171).

A pedometer can be used as a tracking device and can provide instant feedback about activity participation. This information can help in physical activity behavior modification through motivational strategies that are based on achievable step count goals. In 2002, Tudor-Locke et al. (172) conducted a study to examine the utilization of pedometers as a motivating tool for maintaining physical activity levels among obese and sedentary individuals. Every 3 days the step counts were recorded using sealed pedometers i.e. count responses were concealed from subject. It was observed that subjects reported increases in walking behavior and this activity level was sustained for 2 months post-intervention. Thus, the pedometer can function as a motivational and feedback tool (172). Another study reported similar results i.e. an increase in activity level as a result of wearing a pedometer (26).

Studies have shown that pedometers are most accurate in measuring steps taken , less accurate at estimating distance traveled and even less accurate at estimating energy expenditure (17,18,70). For these reasons, researchers have recommended that steps taken, or steps.day^{-1} , be universally adopted as a standard unit of measurement for collecting, reporting, and interpreting pedometer data (143,170).

Pedometers measure step counts and may constitute a practical technique in objective assessment of physical activity and in the subsequent prediction of Kcal expenditure. Pedometer measures do not differentiate between varying intensities of physical activity. Since a pedometer is sensitive to vertical movement but fails to account for the movement intensity, the units prediction algorithm erroneously assumes that the total energy expenditure is similar for walking and running provided the total steps are equal. Various studies using different systems to measure energy expenditure show the correlation between pedometer outputs and measured energy expenditure to be between r=0.46 to 0.88 (171). The doubly labeled water technique is considered to be one of the gold standards in estimating total energy expenditure over a defined period of time; usually 12 or 24 hours (110). Gardner and Poehlman reported a significant correlation (r=0.61) between pedometer counts and measured energy expenditure over a 48 hour period using a doubly labeled water technique (59). However, other studies failed to demonstrate significant correlations between the same variables i.e. r= 0.26 to 0.42 (48,98).

A pedometer measures the volume component of physical activity by recording the total number of steps in a defined time period. However, as noted previously, pedometers do not give quantifiable information about the intensity of a physical activity. In adults the general recommendation is to accumulate 10,000 pedometer measured steps.day^{-1}for health benefits. Depending on the walking speed and body weight, the accumulated 10,000 steps.day^{-1}are approximately equivalent to an energy expenditure of 300-400 Kcal.day^{-1} (67).

In children and adolescents, at least 60 minutes per day of moderate to vigorous intensity physical activity (MVPA) is recommended for health benefits (162). The 60 minutes of daily MVPA translates to accumulation of 12,512 steps.day^{-1} (6-10yr old boys), 11,758 steps.day^{-1} (6-10yr old girls), 11,645 steps.day^{-1} (11-14yr old boys), 11,907 steps.day^{-1} (11-14yr old girls), 12,186 steps.day^{-1} (15-19yr old boys), and 11,290 steps.day^{-1} (15-19yr old girls) in children and adolescents. The recommended steps corresponding to 60 minutes of MVPA vary for age and gender, but the range is narrow (11,290 to 12,512 steps per day). Thus, the single cut point of

12,000 steps.day^{-1} for health benefits is more practical to use and closely meets the target of 60 minutes of MVPA (within 0.3 to 5.5 percentage points) (29).This recommendation measures the volume of the physical activity but does not take intensity into consideration. It was proposed in this investigation that a practical and economic measure of the relative intensity of physical activity is a rating of perceived exertion.

2.8 RATING OF PERECEIVED EXERTION

The perception of physical exertion is defined as the feeling of effort, strain, discomfort, and/or fatigue a person experiences during exercise. It can be used for exercise prescription, to gauge exercise intensity, and for evaluation of exercise program outcomes (116,141,180).

As discussed before, the physical activity recommendations for children and youth advocate participation in moderate-to-vigorous physical activity on a daily basis. Ascertaining the intensity of physical activity that confers the greatest health benefit provides another key component required for evidence-informed physical activity recommendations. Moderate intensity exercise is equivalent to 3 METs energy expenditure while vigorous intensity exercise requires greater than 6 METs energy expenditure (162).The literature supports that most moderate intensity physical activities are equivalent to 3METs energy expenditure in healthy young and middle aged adults. But this may not be true of other populations. The same physical activity level (i.e. intensity) can require different relative metabolic rates between individuals depending on their aerobic fitness levels (95). For example, two people (A and B) have different maximal aerobic power. Individual “A” is highly fit and “B” is low fit. According to ACSM recommendations both individuals should participate in a moderate (i.e.3 METs) intensity exercise program. For “A” a 3 METs activity could require a relative metabolic intensity that is too low to promote significant cardiovascular adaptations. In contrast, for individual “B” the 3 METs intensity may require a relative intensity that is too high to be sustained in the prescribed exercise conditioning session. This prescription problem arises because ACSM exercise guidelines are based on absolute energy expenditure values for a group and do not consider individual differences in aerobic fitness. It is suggested that relative intensity should be used in developing an exercise prescription, as it will be more reflective of individual differences in aerobic fitness.

It has been demonstrated that at the same relative (i.e. percent) exercise intensity, RPE is similar between higher and lower fit individuals even though the absolute power output may be greater in the higher fit individual (101). An accurate and comparatively easy method to estimate relative exercise intensity is by a RPE (137). A RPE provides an estimate of the relative exercise intensity and highly correlates with physiological variables such as HR and VO_2 (137). In addition, a RPE provides a valid method to assess relative intensity for different exercise modes (135,137,138,173), using either progressive or intermittent test protocols. These findings hold for both females and males who vary in age and aerobic fitness (56). A RPE measurement has public health implications as it can be used to report relative exercise intensity in physical activity questionnaires (150) and to self-regulate prescribed aerobic exercise intensity (149).

The concept of and methods to measure exertional perceptions were developed and validated by Gunnar Borg, a Swedish experimental psychologist (22,116). The original RPE (6-20) Scale was developed by Borg in the late 1950’s and early 1960’s. The early scale validation experiments demonstrated a consistent positive relation between HR, VO_2 and RPE during load incremented protocols involving various modes of aerobic exercise. This perceptual-physiological relation formed the conceptual basis of “Borg’s Effort Continua Model”.

2.8.1 Borg’s effort continua model

The theoretical rationale underlying prescriptive applications of RPE is based on the functional interdependence of perceptual and physiological responses during exercise performance. Borg’s Effort Continua Model proposes that the responses to exercise can be described by inter-related physiological, perceptual, and performance continua. As the intensity of exercise performance increases, there is a corresponding and interdependent change in both the perception of physical exertion and associated physiological responses. This linkage indicates physiological (i.e. HR and VO_2) and perceptual responses (i.e. RPE) can provide the same information concerning the intensity of the exercise performance (22,116,141). Thus, RPE can be used independently and/or conjunctively with physiological responses to assess exertional tolerance, self-regulate exercise intensity, and determine physical activity preference.

2.8.2 Physiological mediators of perceived exertion

The physiological mediators that are associated with perceptual signals can be classified as respiratory-metabolic, peripheral, and non-specific (Table 2). Respiratory-metabolic mediators include VO_2, HR, pulmonary ventilation, carbon dioxide production, and blood pressure. Ventilatory drive during dynamic exercise is a particularly important mediator in that it influences chest and breathing input to exertional perception. Depending on the mode of activity, the peripheral mediators are localized to the skeletal muscles of limbs, trunk and/or upper torso.

The peripheral input includes muscle fiber types, free fatty acid concentration, muscle glycogen stores, lactic acid levels, pH, blood flow, and blood glucose. The non-specific mediators of exertional perceptions include hormonal regulation, temperature regulation, pain, cortisol and serotonin levels, cerebral blood flow, and oxygen saturation. These are generally systemic in origin and are not directly linked to either respiratory-metabolic or peripheral signals (141).

Table 2. Physiological mediators of perceived exertion

Respiratory-metabolic	Peripheral	Nonspecific
Pulmonary Ventilation	Metabolic Acidosis (pH, Lactic Acid)	Hormonal Regulation (catecholamines, β-endorphins)
Oxygen Uptake	Blood Glucose	Temperature Regulation(core and skin)
Carbon Dioxide 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	

From Robertson RJ.*Perceived Exertion for Practitioners: Rating Effort with the OMNI Picture System.*Champaign, IL: Human Kinetics;2004. 146 p.(141)

2.8.3 Undifferentiated/differentiated RPE

RPE can be expressed as an undifferentiated measurement for the overall body (RPE-overall) or it can be differentiated separately for limbs (i.e. RPE-legs and RPE-Arms) and chest/breathing (i.e. RPE-chest). The intensity of the differentiated RPE is mediated by the regional muscular factors in limbs and chest, whereas the undifferentiated RPE represents a global perception of exertion for the total body. The undifferentiated RPE measures feelings of exertion for the overall body and represents an approximate averaging of differentiated signals (116,141). The dominant (i.e. highest) differentiated RPE is influenced by exercise type, anatomical origin of the differentiated signal, and the performance environment. Since the dominant RPE varies with exercise type, it should be identified separately for exercises that vary in limb involvement, intensity, and the specific body regions involved. During most weight bearing aerobic exercise the dominant perceptual signal typically arises from the legs. The respiratory- metabolic signal arising from the chest is usually but not universally less intense (123). For the current study the RPE-overall will be used as an indicator of relative intensity during treadmill walking/running and for the development of statistical models to predict Kcal expenditure from the PAI.

2.8.4 Perceptual signal dominance and integration

The two frequently asked questions with regard to differentiated perceived exertion ratings are: (a) What is the mode of integration of the differentiated signals as their separate sensory intensities converge to form the undifferentiated rating of exertion? (b) Which differentiated perceptual signal is the most intense for a given exercise task and/or performance setting, thus, dominating the integration process?

Earlier theoretical models by Simonson et al.(139) and Pandolf et al. (123)postulate that the differentiated ratings are formed at the ordinate level of sensory processing and are closely linked to underlying physiological substrata (123,153). The undifferentiated rating for the overall body appears at the superordinate level of sensory processing and is the net integration of all the differentiated signals. Each differentiated rating of perceived exertion is thought to carry a specific intensity weighting. The differentiated perceptual signals arising from the body regions predominantly involved in the physical activity/exercise have the highest intensity weighting (3) and dominate the sensory integration process. This is true for example of cycling where leg muscles are predominantly active and where muscle mass per unit of work is comparatively small. In this sensory framework the differentiated signals from the legs provide the dominate contribution to the undifferentiated report (129). In contrast, when pronounced regional feedback stems from two discrete anatomical sources such as during wheel-barrow pushing, the undifferentiated perception is higher than either dominant regional signal (135). For maximal treadmill running, the intensity of the undifferentiated rating is often equal to or greater than the dominant signal, regardless of the number of pronounced regional perceptions (135). Thus, the mode of integration must be identified separately for activities varying in type, intensity and number of involved regional signals.

The mode of integration of the differentiated perceptual signals seems to depend on: (a) exercise type, (b) anatomical origin of the differentiated signals, and (c) the performance/environmental medium. The functional link between perceptual signal integration and dominance is best demonstrated during cycle ergometer exercise, where muscle mass per unit of external work is standardized. During cycle ergometry the differentiated signal from the legs is usually more intense than the signal from the chest or the overall body (84). This was demonstrated in a study conducted by Robertson and colleagues (137) who employed a cycle ergometer paradigm where power output was held constant (840 $kgm.min^{-1}$) while pedal rate varied (40, 60, and 80 $rev.min^{-1}$). At each pedal rate, the legs ratings were more intense than the chest ratings. Furthermore, the undifferentiated rating for the overall body appeared as a weighted average of the differentiated legs and chest rating. These data suggest that peripheral signals from active limbs dominate the perceptual integration process during cycling. Signals from the chest reflecting cardiopulmonary and aerobic-metabolic functions are not as pronounced and contribute comparatively less to the perceptual integration process.

Several other experiments have examined the mode of signal integration and sensory dominance during prolonged (60 – 180 minutes) submaximal cycle ergometer exercise (121) and arm plus leg ergometry (114) undertaken at 60-70% VO_{2peak}. During cycle-only exercise, the legs always produced a more intense rating than the chest and thus dominated the perceptual integration process. However, for combined arm and leg ergometry, the arms produced the dominant perceptual signal. In each of these studies, the undifferentiated rating of perceived exertion for the overall body was a weighted average of the differentiated ratings. This means that the overall rating was close to but not exactly the same as the mean of the separate ratings for the legs and chest/breathing. This is consistent with Weiser and Stamper's model which predicts that the undifferentiated perceptual signals reflect the separate input of both the dominant and the less intense differentiated signal (141).

Swank and Robertson (164) reported that during intermittent cycle ergometry the perceptual rating for the legs was more intense than the chest rating at high-intensity exercise (90% VO_{2peak}). For each intermittent exercise bout, the chest and overall body ratings were similar. During incremental cycling RPE-legs was higher than RPE-chest during both exercise and recovery. RPE-legs and RPE-overall reached the highest possible response category at the point of exhaustion, but this was not observed for RPE-chest. RPE-chest increased linearly with increases in physical load, but was always less intense than RPE-legs and RPE-overall (36). Similarly Garcin et al. (58) and Shephard et al. (152) reported that RPE for the legs was more intense than the respiratory perceptual signal arising from the chest during cycle ergometer exercise.

When comparing perceptual responses between intermittent and continuous cycling exercise at the same relative intensities, it was found that RPE for the legs and the overall body were similar throughout exercise (179). RPE-chest was also similar between protocols throughout the exercise sessions. However, RPE-chest increased significantly more at the end of exercise during the intermittent versus the continuous protocol. This time dependent increase in the chest/breathing signals can probably be attributed to the fact that during the intermittent protocol subjects were periodically instructed to increase their power output thus increasing respiratory-metabolic requirements. The increased power output was accomplished by lifting the gluteal musculature off the seat and recruiting upper body musculature in order to rotate the pedals against a greater brake resistance. This alteration in skeletal muscle recruitment increased aerobic energy demand and associated respiratory-metabolic perceptual signals. During the continuous cycle protocol, subjects remained seated as brake resistance increased. As the RPE-chest is linked to respiratory-metabolic demand it was significantly higher at the end of intermittent exercise. The authors concluded that further studies are needed in this area.

Robertson and colleagues (139) also found RPE-legs to be the dominant perceptual signal at the ventilatory breakpoint during an incremental cycle protocol using average and above average aerobically fit children (8-12-year-old). Furthermore, during 60 minutes of constant load cycling, it was reported that RPE-overall and RPE-legs were significantly greater at 30, 40, 50 and 60 minutes than at 20 minutes, whereas RPE-chest only increased significantly after 40 minutes of cycling exercise (64). Thus, these findings also indicate that the differentiated perceptual rating from the legs acts as the dominant signal during cycle ergometer exercise.

However, when perceptual signals arise from two discrete sources, the intensity of the undifferentiated rating can be higher than that of either differentiated rating (57). During maximal treadmill running, the intensity of the undifferentiated rating is equal to or greater than any of the dominant differentiated ratings, regardless of how many regional signals are involved (57,74).

Furthermore, dominance of differentiated sensory signals also persists during the abatement of exertional responsiveness after maximal treadmill running (140). It was found that the rating of perceived exertion for the legs was more intense than the rating for the chest when examined over a 12 minute supine post-exercise period. The undifferentiated overall body rating during the recovery was similar to a weighted average of the differentiated regional (i.e. legs and chest) ratings.

Moreover, an investigation by Robertson and colleagues (134) involving adults walking on a treadmill showed that the onset of a dominant perceptual signal is linked to a specific locomotor speed. Thus, a differentiation threshold (DT) for the ratings of perceived exertion was observed. This was indicated by the walking speed at which the intensities of the peripheral and respiratory-metabolic perceptual signals were first reported to be different from the overall signal of exertion. It was found that at speeds faster than the DT, the dominant signal arose from the legs and was more intense than the integrated overall body signal. In turn, the overall body signal was more intense than the exertion in the chest. In contrast, Pandolf and colleagues (123) reported that at treadmill speeds faster than the DT, the chest signal provided the dominant exertional report. Furthermore, Rutkowski and colleagues (144) found no DT at slow to moderate walking speeds in children.

Thus, these results suggest that the mode of perceptual integration and the dominant perceptual signal should be identified separately for physical activities that vary in type, metabolic intensities, and number ofanatomical regions involved (140).

2.9 RPE-SESSION

RPE-session is a post-exercise measure of perceived exertion experienced for an entire exercise session (53). Several previous investigators propose that the measure is a psychophysiological estimate of the average exertion experienced during either a steady or non-steady state exercise session (49,50). RPE-session was originally used to monitor monotony and intensity of training in athletes. The procedure involved tracking RPE-session for an entire athletic training session. The tracking procedure assumes that a consistent higher RPE-session indicates a higher training load and vice versa. Thus, RPE-session can be used by the athletic coaches to alter the exercise loads to attain an optimal training stimulus to increase performance in athletes and prevent overtraining and staleness.

Initial validation study of the RPE-session measurement was conducted by Foster et al. (49). The experiments employed non-steady state and prolonged exercise. RPE-session was compared with an objective physiological criterion to determine its validity as a measure of training load. Concurrent validity was established by comparing RPE-session with the physiological criterion measures of HR and blood lactate concentration (49). The study concluded that the RPE-session measurement was a valid method of quantifying exercise training load for a wide variety exercise modes. It was also suggested that RPE-session (along with consideration of duration of exercise) has a potential to quantify exercise training independent of mode and intensity (49). The concurrent validation and reliability of RPE-session was also examined by correlating VO_2 and HR averaged for the entire aerobic exercise bout with the RPE-session. Results indicated strong and significant correlations between RPE-session and $\%HR_{peak}$ (r^2=0.74), $\%VO_{2peak}$ (r^2=0.76), and $\%HR_{reserve}$ (r^2=0.71). The % HRmax and $\%VO_2$ maxvalues were determined for low, moderate, and high exercise intensities. The RPE at these intensities corresponded to EASY: 1-2, Somewhat hard: 3-4 and Hard: 7-8 respectively on the scale. The reliability correlation coefficients were significant for RPE-session (r=0.88), $\%HR_{peak}$(r=0.98), $\%VO_{2peak}$ (r=0.98), and $\%HR_{reserve}$ (r=0.98). The results suggested that RPE-session was both a valid and reliable method of monitoring exercise training load (175).

Construct validity of RPE-session involves the comparison of the RPE-session response obtained post-exercise (usually 5 or 30 minutes) to the mean of the momentary RPE response measured during the actual exercise session i.e., RPE mean. The RPE mean is calculated as the average of the momentary RPE response obtained at periodic intervals during the exercise bout. Previous investigations involving adults have established construct validity of the RPE-session measured using the Borg category ratio (0-10) scale during steady state aerobic exercise (49,175), intermittent aerobic exercise (165), and resistance exercise involving different muscle groups (190) and various intensities (6,166).

Thekkada et al. (165) examined RPE-session responses of recreationally active, college age subjects who completed three intermittent aerobic exercise bouts on the treadmill. Each of the three exercise bouts lasted 5 minute separated by a 5 minute rest period. The intermittent aerobic exercise consisted of a level walk (LW) at 4.02 $km.hr^{-1}$at 0% grade, hill walk (HW) at 5.63 $km.hr^{-1}$and 5% grade and run (R) at 8.05 $km.hr^{-1}$ and 2.5% grade. The bouts were presented in counterbalanced order. The OMNI Walk/Run Perceived Exertion scale was used to measure RPE-overall during each minute of the exercise bout. Five minutes post-exercise a RPE-session (Overall body) was measured using the same scale. No significant difference was found between the RPE-session (O) and the RPE-mean. In addition, the two RPE variables were highly correlated (r=0.84). In general this investigation concluded that RPE-session is a valid method to monitor global exertion experienced during intermittent exercise (165).

Recent research has focused on the use of RPE-session in non-athletic subjects to monitor the intensity of physical activity. Kilpatrick et al. (85) examined changes in RPE-session, where exercise duration was held constant at different self-regulated exercise intensities. The adult male and female subjects exercised at a self-selected intensity corresponding to verbal descriptors “light”, “moderate” and “vigorous” for 30 minutes. It was observed that RPE-session was higher ($p<0.05$) than the mean of momentary RPE (i.e. RPE-mean), but was not significantly different ($p<0.05$) from momentary RPE obtained at the latter stages of the exercise test. Thus, this study indicated that RPE-session is comparatively better representation of the exertion experienced during the final minutes of an exercise session. Green et al. (63) studied the impact of exercise intensity on RPE-session during different modes of exercise i.e. cycling and treadmill exercise. The subjects (adult males) exercised at 50 and 75% of mode specific VO_2max with the duration adjusted to achieve similar energy expenditure of 400 Kcals across intensity conditions. The RPE-session was obtained 20 minutes post-exercise session. For both modes of exercise, RPE-session was significantly greater ($p<0.05$) for the higher intensity. Thus, this study suggested that rather than duration of exercise or total Kcal expenditure, RPE-session is primarily driven by intensity of exercise.

2.10 THE OMNI SCALE OF PERCEIVED EXERTION

The OMNI Scale of Perceived Exertion was developed by Robertson et al., at the Center for Exercise and Health Fitness Research at the University of Pittsburgh (141). The term OMNI is a contraction of the word omnibus, “which in this context means that the perceived exertion scale is applicable for a wide range of clients and physical activity settings (p. 10)” (141).

The OMNI Scale of Perceived exertion was developed for use with children and adults of mixed ethnicity and gender. The OMNI Scale uses a standard set of numerical categories and verbal descriptors. The scale's pictorial descriptors are interchangeable in order to be generally consistent with the type of exercise to be performed. The scale's numerical categories range from 0 to 10 and depict gradually increasing exercise intensity, such as encountered when going up a hill. The OMNI Scale pictures show individuals participating in different types of physical exercise, yet the verbal cues and their corresponding numerical ratings are always the same. The correct OMNI pictorial for a particular exercise activity is selected by matching the exercise mode depicted on the scale with the type of physical activity to be performed.

2.10.1 Development of the OMNI Scale of perceived exertion

The development of the OMNI Scale of perceived exertion occurred in four steps (141). First, a series of pictures were drawn by an artist, depicting an individual at various levels of exertion while performing activities such as cycling, progressing from a walk to a run, stepping, and weightlifting. For each exercise mode a set of four pictures was drawn, featuring both female and male children and adults. To maximize generalization over normal variations in human skin tones, all pictorials were drawn in shades of gray on a white background.

The second step involved showing the picture sets for each exercise type to children and adults and having them describe the level of physical exertion depicted by the pictorials. Verbal responses to the pictorials were accepted if they met one of the following criteria: (a) described effort or exertion, (b) pertained to the intensity of exercise or work, and (c) described either body signs or symptoms of exercise discomfort or comfort.

In the third step, semantic differential analysis was used to select verbal descriptors from the initial pool of responses that met the above mentioned criteria. Six verbal descriptors were chosen. Each conveyed a discrete level of exertional intensity. Using the semantic differential analysis, a set of verbal cues was identified that shared common meanings among children and a separate set was selected that shared common meanings among adults. The key words that were included in the adult scale were *easy* and *hard*. The key word for the children's scale was *tired*.

During the fourth and final step, the six semantically discrete verbal cues were positioned at equal intervals along the 0 to 10 category scale, as were the four pictorials. Thus, a general correspondence was achieved between the verbal and picture cues, each depicting a discrete level of perceived exertion. The scale was presented on an exertion format depicting a gradually increasing perceptual intensity gradient. This four step process was used to develop a series of OMNI Scales for use by adults and children during weight-bearing (walk/run) and non-weight bearing (cycling) exercise.

2.10.2 Validation of the OMNI Scale of perceived exertion

The validity of the OMNI Scale of Perceived exertion has been established using load incremented treadmill and cycle ergometer tests. The various OMNI Scale formats were validated using such physiological variables as VO_2 and HR as criterion measures. Validity coefficients ranged from $r = 0.67$ to 0.88 ($p < 0.05$) for the walk/run format, and from $r = 0.81$ to 0.95 ($p < 0.05$) for the cycle format. Reliability coefficients for the OMNI Scale range from $r = 0.91$ to $r = 0.95$ (141).

2.11 CHILD OMNI WALK/RUN SCALE OF PERCEIVED EXERTION

The OMNI Perceived Exertion Scales are available in various formats to accommodate differences in age and mode of activity. With respect to age, the pictorial and verbal descriptors of the Child OMNI Scale are intended for use with pediatric population ranging in age from 8 to 14 years. Children typically do not have the vocabulary or the cognitive ability to understand verbal descriptors used in adult formatted scales (109,136,184). Thus, there have been a number of investigations that have attempted to develop valid RPE scales for children (40,41,43,44,65,184,189).

For the pediatric population, it is important to include age appropriate and understandable numbers, verbal descriptors and illustrations when developing RPE scales. It especially is important to include meaningful child-like pictures along with developmentally appropriate verbal descriptors in order for children to have a greater understanding of the effort continuum (116). The pictures help to fine tune the ability to rate the intensity of perceived exertion. Therefore, in 2000 Robertson and colleagues developed the OMNI Scale of Perceived Exertion for children. This scale consisted of pictorial cues arranged in consonant with verbal descriptors. Semantic differential analysis indicated that the verbal descriptor most used by children to describe their level of perceived exertion is “tired”. Thus, verbal descriptors that children can associate with being tired during physical exertion were integrated into the scale format. The four mode specific pictorial descriptors for the Child OMNI Scale were placed along an ascending perceptual intensity gradient. The pictorials were positioned above four numerical categories , and the corresponding verbal descriptors *not tired at all, a little tired, getting more tired, tired, really tired, very, very tired*. This established a verbal-visual correspondence along the perceptual intensity gradient (137). The Child OMNI Scale was initially developed for cycling exercise. Later Utter and colleagues (2002) developed a pictorial version of the Child OMNI Scale for walking and running exercise (Figure 2).

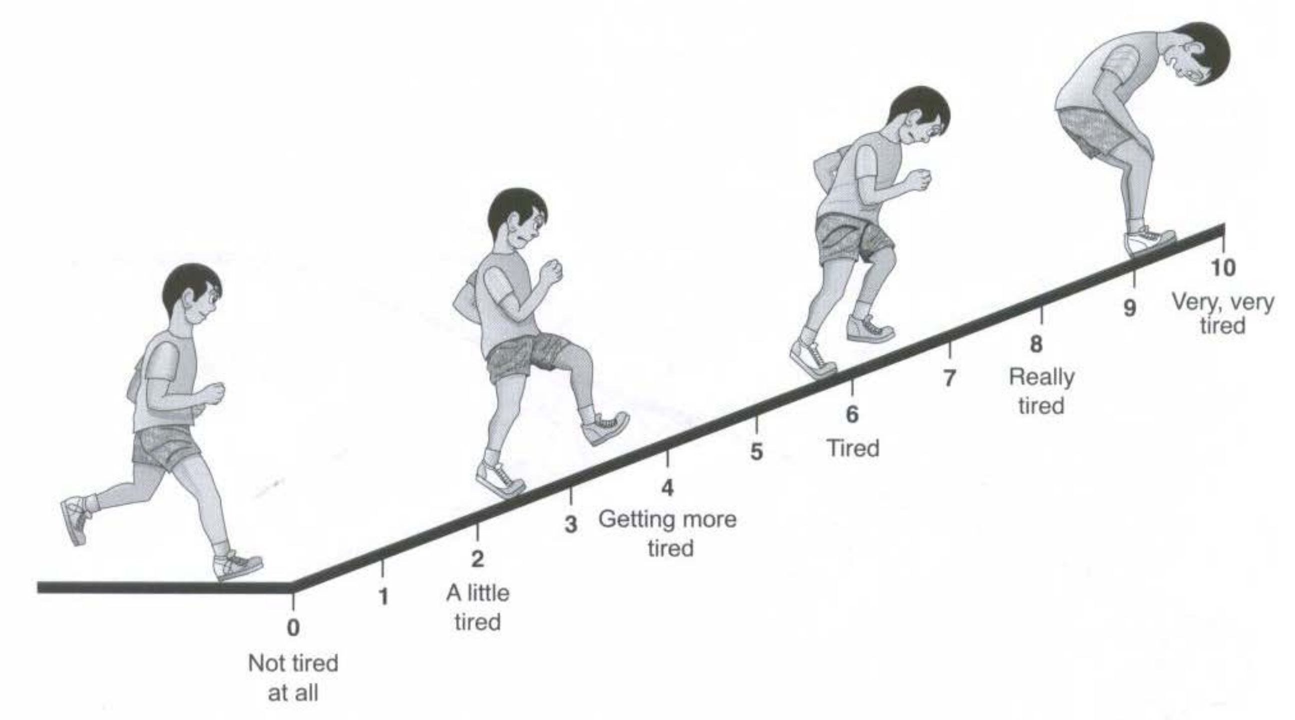

Figure 2. Child OMNI-RPE Walk/Run Scale of Perceived Exertion

Robertson RJ. *Perceived Exertion for Practitioners: Rating effort with the OMNI Picture System.*Champaign, IL. Human Kinetics.2004.146 p (141).

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The Child OMNI Walk/Run scale uses the same numerical categories and verbal descriptors as the Child OMNI Cycle Scale. However, the pictorials were interchanged to represent children at varying levels of intensity while walking and running up a hill/incline. Correlation coefficients for the relation between OMNI Scale RPE and the selected physiological criterion variables were as follows: VO_2: r =0.32; $\%VO_2max$: r =0.42; HR: r =0.40; ventilation: r = 0.33. While the correlation coefficients were low, all physiological variables had a significant relation with the undifferentiated RPE. This study demonstrated that the Child OMNI Walk/Run Scale was a valid metric for determining RPE in children during walking and running exercise (174).

For the current investigation, the subjects (children and adolescents) performed a maximal treadmill test. Therefore, RPE was obtained using the Child OMNI Walk/Run Scale and served as the relative intensity component of the PAI energy cost prediction model.

2.12 INDICES INVOLVING THE OMNI SCALES

Recent studies employing the OMNI perceived exertion picture system demonstrate statistical difficulties when a “0” rating is used in the computation of an exercise related indices such as the PAI. When computing the PAI, a “0”category rating results in a “0” index value. This occurs when a RPE response of “0” is multiplied by the corresponding step count. In mathematical terms, any integer multiplied by a “0” will yield a “0”. This presents challenges when performing statistical computations using values derived from RPE based indices (38,107).

Another psychophysical calculation where the “0” category on the OMNI Scale can potentially present computation difficulties is the Exercise Discomfort Index (EDI). The EDI is calculated as the product of RPE and a rating of muscle hurt/pain (RMP) (38,94). Both the OMNI perceived exertion scale and the OMNI muscle hurt/pain scale have a “0” category. As such, the derived index will yield a “0” if either an RPE or RMP is reported as a “0” category.

Thus, it is important to modify the standard OMNI Scale format by either eliminating the “0” category as a possible exercise response or to specifically link the “0” category to a resting (i.e., non-exercise) state. The validity of three alternative Adult OMNI RPE Scale formats that omit the “0” category as its lowest anchoring point or link a “0” category to a true rest period was examined. Concurrent validity was established by regressing RPE at 40%, 65%, and 90% VO_2peak against corresponding values for VO_2 (r=0.88 to 0.94) and HR (0.81 to 0.91).Construct validity was examined by regressing RPE derived from Alternative Adult OMNI-Cycle Scales against RPE derived from the Original OMNI-Cycle Scale. RPE derived from the Alternative and Original Scales corresponded to 40%, 65%, and 90% VO_2peak. The regression analyses indicated that RPE derived from the three Alternative Adult OMNI-Cycle Scales were positively related (r = 0.93 to 0.98) to the RPE derived from the Original Adult OMNI-Cycle Scale. All regression analyses were statistically significant ($p<0.001$) and thus established construct validity for the three Alternative OMNI-Cycle Scales. It was concluded that the alternative formats of the Adult OMNI-Cycle Scales, where the zero category was eliminated or represented a resting state and not an exercise response, is a valid measure of perception of exertion during cycle ergometer exercise (124).The present study employed the original walk/run format of the Child Walk/Run OMNI Perceived Exertion Scale to assess RPE. As such, the calculated PAI could have been negatively biased (i.e. lower RPE values) given the presence of a “zero” category in the calculated index. An informal attempt was made to identify whether such a scale bias occurred by adjusting each RPE response by a scale category of one. The effect was to mathematically create a perceptual response range of 1 to 11 with all RPE representing exertional conditions only. As such a data adjustment has not been experimental validated, the calculated PAI values presented in the discussion to examine this possible scaling bias are intended to be preliminary in nature.

2.13 KCAL PREDICTION MODELS

2.13.1 PAI Kcal prediction models

There are two published studies that examined the validity of Kcal prediction models using the PAI scores (176,178). Both studies were conducted using adult subjects. The preliminary study was conducted using sixteen recreationally active college aged (23 yr) male and female subjects. Measurements were obtained separately for three different intermittent treadmill exercise bouts and were equivalent to 30%, 55%, and 80% VO_2max as determined for individual subjects. The study reported a positive correlation of r=0.69 between PAI and Kcal expenditure when responses were examined across the three relative exercise intensities (176).

The second study examined the development and validity of the PAI in estimating total Kcal expenditure for three different submaximal treadmill intensities in recreationally active college-aged (20 yrs) females (178). The experimental protocol employed three counterbalanced intermittent submaximal 10 minute exercise bouts of low, moderate, and high intensity. The Kcal expenditure was estimated from a regression model that employed PAI as the predictor variable: Predicted Kcal = 27.152 + 0.007 (PAI score) $p < 0.05$, SEE = 14.04, r = 0.86, $r^2 = 0.74$ (178).

Weary et al. (178) reported that during sub-maximal exercise, actually measured Kcal using the PAI correlated significantly ($r=0.86$, $p<0.05$) with energy expenditure derived by indirect calorimetry (178). Weary et al. further reported that at lower exercise intensity, PAI over-predicted ($p<0.05$) Kcal expenditure explaining a significant portion of the variance (i.e. $r^2=0.74$). The accuracy of the PAI model in predicting Kcal expenditure was comparatively greater for moderate and higher exercise intensities than for the lower intensity (178). The difference between predicted and measured Kcal expenditure may be attributed to varying levels of accuracy of pedometers at different walking speeds, plus individual differences in gait cycles and stride length (35). It was concluded that a PAI based model can accurately estimate Kcal expenditure in young women performing a moderate intensity treadmill exercise bout (178).

Lagally et al. (93) investigated the relation between PAI score and derived energy expenditure using the Sensewear armband to estimate energy expenditure among 6^{th} – 8^{th} graders (11-14 years old) children. The data was collected during Physical Education class session and the exercise intensity was not controlled. The subjects participated in fitness type activities such as step aerobics, weight training for 30 minutes. At 10 minute interval, the activity was paused and sensewear armband was time stamped; step counts and RPE response were obtained. The study reported low to moderate correlation values (r=0.16-0.44) between the PAI scores and armband measured energy expenditure. This is the only published study of PAI among pediatric population.

However, the absence of standardized methodology in measuring the two components of the PAI (step counts and RPE) makes interpretation and generalization of the derived PAI questionable.

2.13.2 Kcal prediction models using physical activity monitor

Physical activity monitors are mechanical and electronic devices that record motion or acceleration of a limb or trunk, depending on where the monitor is attached to the body. There are several different types of physical activity monitors that range in complexity and cost from the pedometer to the triaxial accelerometer. The following section discusses the available literature on predicting Kcal expenditure using physical activity monitors.

2.13.2.1 Pedometer Kcal prediction models

Studies have shown that pedometers are most accurate in measuring steps taken , less accurate at estimating distance traveled and even less accurate at estimating energy expenditure (18,20,70). For these reasons, researchers have recommended that steps taken, or steps.day^{-1}, be universally adopted as a standard unit of measurement for collecting, reporting, and interpreting pedometer data (143,170).

The physical activity energy expenditure among African American children was investigated using Tritrac accelerometer and Digiwalker pedometer, with DLW as criterion method. The study employed 7-10 year old and physical activity and energy expenditure were measured over seven consecutive days under free-living conditions. A stronger correlation between pedometers and accelerometers (r= 0.88) than between pedometers and the doubly labelled water method (r= 0.67) was observed. This indicates that pedometers and accelerometers are equally good in measuring step counts (130).

Mitre et al. (108) investigated the accuracy of two commercially available pedometers (Omron and Yamax) in measuring step counts among normal weight and overweight children. Sixteen children (boys and girls) of normal weight and 11 children (boys and girls) who were overweight completed 5 minute walking bouts at 0.5, 1.0, 1.5, and 2.0 mph. The steps taken during each bout were measured using pedometers and also counted manually. The manual counts were then compared with measured step counts to examine the accuracy of pedometers. It was observed that there was significantly greater error in pedometer step count measurement among overweight children than in normal weight children. Also, the percentage error was higher for slower speeds than for the fastest speed of 2 mph (108). Similar results were reported by Crouter et al. (34) with respect to accuracy of pedometers. This study investigated the effect of walking speed on the accuracy of pedometer step counts, distance covered, and predicted energy expenditure. It was observed that pedometers were less accurate at slower speeds than at faster speeds. The authors concluded that pedometers underestimate energy expenditure during lifestyle activity (141).

Stone et al. (161) investigated the effect of age and anthropometric variables in estimating energy expenditure among 8-40 year olds using five different motion sensors. The five motion sensors were commercially available Yamax pedometers and accelerometer. Subjects walked at 3 different speeds – Speed 1; 4-6km.hr^{-1}, Speed 2 – 5-10 km.hr^{-1}, Speed 3 –

7-12 $km.hr^{-1}$. Speed 1 required slow walking, speed 2 required fast walking and/or slow jogging speed, and speed 3 required fast running speed. The pedometer counts provided the best estimation of energy expenditure at speed 2 and speed 3(r^2=0.0.96). Thus, pedometers are a valid method of physical activity and associated energy expenditure measurement, particularly at moderate and fast speeds.

Kumahara et al. (91) examined the adequacy of step counts in assessing energy expenditure in adults. The 24-hour energy expenditure was measured using a large (i.e. room size) respiratory-metabolic chamber. The caloric expenditure was assessed for such activities as sleeping, watching television, reading, deskwork, washing, and walking on a treadmill at 3.9 and 5.1 $km.hr^{-1}$ for 30 minutes each. The subject wore a piezo-electric uniaxial pedometer to measure total step counts for 16 hours a day. It was observed that the step count did not correlate (r= -0.13) with physical activity related energy expenditure measured by indirect calorimetry. Thus, total step count was not a meaningful predictor of energy expenditure in this study (91).

Leenders et al. (98) studied the association between measured energy expenditure and physical activity assessed by various methods among women in a free-living condition. The doubly labeled water technique (DLW) was used to measure total daily energy expenditure and indirect calorimetry was used to assess resting metabolic rate and peak oxygen uptake (VO_2 peak). The total daily energy expenditure was measured for 7 days and subjects wore the activity monitor (Yamax-Digiwalker-500 pedometer) for the same 7 day period. In comparison with DLW measurements, average physical activity related energy expenditure was 497 Kcal less than that estimated by pedometry. It was observed that the pedometer significantly underestimated (by 59%) free living physical activity related energy expenditure. It was concluded that a pedometer can be used as an economic and practical instrument to discriminate between activity levels, but step counts may not provide an accurate estimate of physical activity related energy expenditure (98).

Eston and Rowlands (42) conducted a comparative study of the accuracy of HR monitoring, pedometry, and accelerometry to predict energy expenditure (scaled oxygen uptake) among 30 children (15 boys and 15 girls). The children participated in various activities such as walking, running, hopping, catching, sitting, and crayon drawing. In addition, VO_2 was measured during walking speeds of 4 and 6 $km.h^{-1}$ and running speeds of 8 and 10 $km.h^{-1}$. A significant correlation (r=0.782) was observed between VO_2 and hip positioned pedometer step counts during treadmill exercise. For play activities the correlation was r=0.921. The pedometer step count also significantly correlated with HR (r=0.816) during treadmill exercise. All measures of step count and locomotor speed were positively correlated. These findings suggested that pedometers were an effective and affordable means of estimating exercise intensity in children (42).

Depending on the aerobic fitness level, population sample characteristics, and the type of energy expenditure measurement, the relation between pedometer step counts and energy expenditure can be different. This difference can also be attributed to the pedometer's inability to measure exercise intensity.

2.13.2.2 Accelerometer Kcal prediction models

In a study comparing energy expenditure predicted by a Caltrac activity monitor and daily total energy expenditure (TEE) derived from doubly labeled water, Johnson et al. concluded that a measure of movement counts was not a meaningful predictor of energy expenditure (77). The caloric estimates (956 kcals per day) of energy expended in physical activity derived from the

Caltrac were significantly higher when compared to measured (i.e. doubly labeled water) active energy expenditure (469 kcal per day) in children participating in a free- living setting.

A study conducted by Ishikawa-Takata et al. (75) investigated the accuracy of the triaxial accelerometer in assessing physical activity energy expenditure (PAEE) among adolescents. The study compared PAEE assessed by accelerometry ($PAEE_{Acc}$) and that determined by the doubly labeled water ($PAEE_{DLW}$) method. A significant correlation of r=0.551 (p<0.001) was observed between $PAEE_{DLW}$ and $PAEE_{Acc}$ among all subjects. The correlation values were higher for regular exercisers (r=0.522, p=0.002) than for non-exercisers (r=0.196, p=0.318), possibility attributable to the error in the assessment of exercise intensity by both methods (75).

Trost et al. (169) conducted an experiment to quantify energy expenditure in 10-14 year old children during walking and running on a treadmill using Computer Science Application counts (uniaxial accelerometer) and kcal expenditure derived from oxygen consumption adjusted for RER. The correlation between actual (derived from oxygen consumption measures) and predicted mean energy expenditure (estimated from CSA counts) at each of three treadmill speeds (3, 4, and 6 miles.hr^{-1}) was r=0.85, r=0.62 and r=0.81 respectively. They also reported that the standard error of estimate increased with treadmill speed (from 3 miles.hr^{-1}to 6 miles.hr^{-1}) as a result of lower accelerometer outputs (i.e. counts/min) during running. The lower movement counts during the running mode may have been due to lower sensitivity of the accelerometer architecture to vertical displacement of the body's center of mass as stride frequency increased.

Previous investigations have employed leg length, stride length, stride frequency, anthropometric and physiological as predictor variables in estimation of energy expenditure during weight bearing aerobic exercise. It was reported that measured energy expenditure correlate with these variables (181). Stone et al. (161) investigated the effect of age and anthropometric variables in estimating energy expenditure among 8-40 year old subjects using five different motion sensors. The five motion sensors were commercial available pedometers and accelerometers. Subjects walked at 3 different speeds – 4 to 6km.hr^{-1}, 5 to 10 km.hr^{-1}, 7 to 12 km.hr^{-1}. The accelerometers and pedometers provided the best estimation of energy expenditure at 5 to 10 km.hr^{-1} (r^2=0.48 to 0.96). The strongest correlation values (r^2=0.90 to 0.96) were observed for the pedometer models across all the speeds. The study also reported that the difference between measured and estimated energy expenditure increased as the leg length increased. Also, the increased prediction error in taller participants was exacerbated with increased speed in all models. (161).

Overall, physical activity monitors provide a valid measure of physical activity over a defined time period (182), but estimations of energy expenditure based on these derived movement counts is less accurate. In general, these monitors overestimate energy expenditure for activities with a small force: displacement ratio such as jumping, running. Conversely, they underestimate energy expenditure for activities with large force: displacement ratios such as stair climbing and knee bends (110). An additional problem, related to the use of prediction equations, is that they assume steady-state exercise and metabolic status over a one-minute exercise interval. Consequently, if a child alternates between vigorous physical activity and rest or low intensity activity within a given minute (typical child’s play), the movement counts for that minute will reflect only the average activity level during that period not the intensity of the activity (168). Because movement count monitors do not differentiate between varying intensities of physical activity, the accuracy of energy expenditure prediction models is compromised.

2.13.3 RPE based Kcal prediction models

Few studies have reported using RPE to estimate energy expenditure during physical activity. Novas et al., (117) developed prediction models using RPE to estimate energy expenditure during a tennis match played by elite female tennis players. A significant correlation of r=0.89 ($p<0.05$) was observed between energy expenditure derived from RER adjusted oxygen consumption and RPE. The energy expenditure for a 60 minute single tennis match was measured using indirect calorimetry. The estimated energy expenditure for the same tennis match was also using RPE and HR regression equations. RPE overestimated energy expenditure, but the error of estimation was less than 5% whereas for HR the prediction error was 20.7%. The study concluded that RPE was a practical and more accurate method than HR to estimate energy expenditure during tennis.

A study by Moyna et al. (113) developed performance duration guidelines across six exercise modalities. Each modality required a total energy expenditure of 200 kcal using a target RPE to self-regulate exercise intensity. The RPE zones used in the developed guideline chart were low (RPE-11), mid (RPE-13), and high (RPE-15) on the 15 category Borg RPE scale. It was observed that the time to expend 200 Kcal decreased, as the RPE increased with in a given exercise mode. On treadmill, the estimated time for males to expend 200 kcal at a target RPE of 11 was 14 minutes. For the same subject 11.5 minutes were required to expend 200 Kcal at a target RPE of 15 (113).

The Kcal expenditure can be determined using VO_2 measures with accompanying RER adjustments for different substrate utilization and the RER (24).There is no known kcal prediction equation where RPE was the primary predictor of Kcal expenditure during walking exercise. However, there are numerous studies reporting efficacy of using RPE to predict oxygen uptake during aerobic exercise (45). The submaximal RPE values are effectively used in predicting VO_2max. RPE provides accurate estimates of VO_2max regardless of fitness level, gender or exercise mode in adults (45). There are no published studies employing RPE and RPE-session to estimate VO_2max and/or Kcal expenditure in children and adolescents.

2.14 POTENTIAL ROLE OF PHYSICAL ACTIVITY INDEX IN EXERCISE PRESCRIPTION

An effective exercise prescription includes both volume and intensity as key components. The PAI incorporates both of these exercise components. The PAI is economical, easy to use, and provides objective and subjective monitoring of aerobic activities. Thus, Weary et al., (178) proposed that once validated across a range of activity types the PAI can enhance adherence to exercise programs (178).

The PAI provides an easy tool for Kcal expenditure estimation in adults (178). It was proposed in the present investigation that the PAI can be used to measure Kcal expenditure in a pediatric population subset. Such application could be of significant value for weight management interventions for the pediatric population.

The previous two studies validating use of PAI to estimate energy expenditure were conducted using college age, recreationally active males and females (176,178). However, there is no published research on the validity of the PAI for use in a pediatric population. The only published study on children demonstrates a weak to moderate correlation (r=0.16-0.44) was between the PAI scores and energy expenditure (93).It was expected that the findings of the present investigation will indicate that the PAI can be effectively used to predict Kcal expenditure of a selected cohort of children and adults performing load incremented treadmill exercise. It was proposed that a pediatric version of the PAI can be an effective component of exercise programming to further help in obesity prevention and can also act as motivation tool for maintaining a physically active lifestyle in children.

In summary, this chapter initially discussed obesity prevalence, co-morbidities associated with obesity, and the role of physical activity in combating obesity and associated disorders in the pediatric population. The goal of the literature review was to emphasize the importance of both the volume and intensity components of an exercise prescription and to discuss the validity of a perceived exertion based PAI to predict Kcal expenditure in children/adolescents performing load incremented treadmill exercise. It was proposed that the PAI is a low burden and valuable instrument in physical activity programming for children and adolescents.

3.0 METHODOLOGY

3.1 SUBJECTS

This investigation undertook a secondary analysis of data collected as part of a parent study titled "Childhood Metabolic Markers of Adult Morbidity in Blacks". The parent study was funded by an NIH R01 grant and was conducted at Children's Hospital of Pittsburgh, under the direction of Dr.Silva Arslanian (Principal Investigator).

The subjects were recruited from the greater Pittsburgh area, including the University of Pittsburgh campus. The recruitment advertisement appeared on bulletin boards, newspapers, radio, Craigslist, public transportation (bus boards), and community events. The study participants were also recruited from various youth social and sporting programs by talking with parents and distributing fliers. Using Cole's directory, blinded recruitment letters were sent to random zip code addresses. The subjects were also recruited from the Community Leisure Learn Program at Trees Hall, University of Pittsburgh.

The subject inclusion criteria for the parent investigation were males or females aged 8-17 years, who had a BMI $\geq 10^{th}$ percentile for a given age category. The participants were self-identified African American or White American with no admixture for three generations. All participants were in good health on the basis of clinical history, physical examination, and hematologic profiles. No participant was receiving medication that altered metabolism. A

Hemocue <12gm.dl^{-1} in pubertal subjects and <11gm.dl^{-1} in prepubertal subjects, positive serum pregnancy test and recent significant weight change or dieting were exclusion criteria for potential subjects.

The data used for the secondary analysis were obtained during the exercise testing portion of the parent investigation conducted from 2005-2009. The sample for the present analysis is a subset of the entire sample for the full parent investigation. To be selected as a part of the subset each subjects' total step count data must have been available for analysis. The subset of subjects (N=84)that met inclusion criteria were 8-17yr old children and adolescents, who underwent maximal treadmill testing at the Center for Exercise and Health-Fitness Research, Trees Hall at the University of Pittsburgh. The total step count data for these 84 subjects (male n=43, female n=41) were used to conduct statistical analyses 4and 5 involving the PAI (session). A group consisting of 49 subjects was then identified from the primary subset of 84 subjects. These 49 subjects (male n=28, female n=21) had pedometer step count data available for each stage of the treadmill test. The data for these 49 subjects were used for the statistical analyses 1, 2, and 3, where PAI is calculated using momentary RPE.

All children were studied in the Pediatric Clinical Translational Research Center (PCTRC) at Children's Hospital of Pittsburgh of UPMC and at the Center for Exercise and Health-Fitness Research, Department of Health and Physical Activity at the University of Pittsburgh. The subject's weight and height were obtained by a PCTRC nurse using a standard scale and stadiometer. These data were used to calculate BMI for inclusion purposes. All studies were approved by the Human Rights Committee of Children's Hospital of Pittsburgh and the University of Pittsburgh's Institutional Review Board. Research participants and parents or guardians gave written informed assent and consent, respectively, after receiving a thorough explanation of the research project.

3.2 EXPERIMENTAL DESIGN

The investigation employed a single observation, cross-sectional design. All participants were admitted to the PCTRC in the early afternoon before testing procedures were initiated. Provided the physical examination was clinically normal, participants were transported to the Center for Exercise and Health-Fitness Research in Trees Hall at the University of Pittsburgh, where a physical activity questionnaire and VO_2max test were administered. At the Center for Exercise and Health-Fitness Research, orientation procedures and data collection were performed in following order:

- Test orientation and perceived exertion scale instructions and anchoring
- Maximal treadmill test
- RPE-session assessment
- Physical activity questionnaire

3.2.1 Test orientation: OMNI-RPE Scale and treadmill protocol

The subject was oriented to the Child OMNI-RPE Walk/Run Scale of Perceived Exertion (Figure 2) using standard instructions and anchoring procedures.

The exercise test and perceived exertion instructions were short, precise and specific to the mode of exercise that the subject performed. The instructions satisfy the physiological-perceptual linkage as depicted in Borg’s Range Model of category scaling. The instructions explained to the subject how to link the lowest and highest verbal descriptors, pictorial descriptors, and numerical categories with their perceptions of very low and very high levels of exertion. Cognitive anchoring procedures were used to reinforce the instructions and facilitate understanding of the OMNI-RPE scale response range (141).The Child OMNI Walk/Run scale was validated by Utter and colleagues in 2002.This study demonstrated that the Children’s OMNI Walk/Run Scale was a valid metric for determining RPE in children during walking and running exercise (173). The Child OMNI scale (see Figure 2) has both verbal and pictorial descriptors distributed along a numerical category range from 0 to 10. A unique feature of the OMNI Scale system is that it employs interchangeable sets of pictorial descriptors that are intended to be generally consonant with the exercise bring performed i.e. walk/run. The OMNI scale is presented in a visually discernible exertional format, appearing as an ascending intensity gradient. The pictorial and verbal descriptors provide cognitive cues to help in rating exertional perceptions at various exercise intensities.

The definition of perceived exertion and OMNI scaling instructions were as follows:

Definition: How tired does your body feel during exercise?

Instructions: We would like you to walk and then run on a treadmill for a little while. Every few minutes the treadmill speed will get a little faster. Please use the numbers on this picture to tell us how your body feels when exercising on the treadmill. Please look at the person at the bottom of the hill who is just starting to walk (point to the left pictorial). If you feel like this person when you are on the treadmill you will “not be tired at all.” You should point to a 0 (zero). Now look at the person who is barely able to run to the top of the hill (point to the right pictorial). If you feel like this person when you are running on the treadmill you will be “very,

very tired." You should point to number 10 (ten). If your feelings are somewhere in between "not tired at all" (0) and "very, very tired" (10), then point to a number between 0 and 10. We will ask you to point to a number that tells how your whole body feels, how your legs feel and how your breathing feels. Remember, there is no right or wrong answer. Use both the pictures and words to help select the numbers. Use *any* of the numbers to tell how tired you feel when walking and running on the treadmill.

The low and high perceptual anchors for the OMNI-Walk/Run Scale were established using a visually interfaced cognitive procedure. This procedure requires the subject to cognitively establish a perceived intensity of exertion that is consonant with that depicted visually by the figure walking at the bottom (i.e., low anchor, rating 0) and top (i.e., high anchor, rating 10) of the hill as presented in the OMNI Walk/ Run Scale illustrations.

Perceived exertion was measured as an undifferentiated rating for the overall body (RPE-overall) and a differentiated rating for the legs (RPE-legs) and breathing perceptions in the chest (RPE-chest). Because a mouthpiece prohibited a verbal rating response, subjects pointed to their RPE on the scale. The OMNI-Walk/Run Scale was in full view of the subject at all times during testing. The RPE was confirmed by the investigator who repeated the perceptual response to the subject.

The procedures to perform the maximal treadmill test were explained as follows:

Instructions- Start by straddling the belt of the treadmill. Once the treadmill starts, we would like you to walk at a slow speed for a warm-up. This warm-up will help to familiarize you with the treadmill. After the warm-up, the actual test will begin. Every 3 minutes during the actual test, the treadmill belt will get a little faster and the treadmill will get steeper. There are five stages in the treadmill test. The first two stages of the test are like walking up a hill. During the third stage you will probably have to begin running. During the fourth and fifth stage you will be running uphill. The test continues as long as you want it to continue. When you want to stop signal us, and we will stop the treadmill. It takes a little time for the treadmill to stop, so continue walking/jogging until the belt comes to a complete halt. Make sure that you keep walking/running until the treadmill stops completely.

Following the orientation procedures the subject performed a maximal graded treadmill test.

3.2.2 Maximal treadmill test

VO_2max was assessed using a Bruce treadmill protocol. The Bruce protocol employs continuous incremental exercise stages. The protocol is considered moderately aggressive and is one of the most commonly used tests to assess aerobic fitness. According to ACSM the Bruce protocol is best suited to evaluate young and/ or physically active individuals. The Bruce protocol consists of 5 stages, each 3 minutes in duration. For each stage, the workload was increased by incrementing both treadmill speed and grade as follows: Stage 1: 2.73km.h^{-1} at 10% grade; Stage 2: 4.03km.h^{-1} at 12% grade; Stage 3: 5.47km.h^{-1} at 14% grade; Stage 4: 6.76km.h^{-1} at 16% grade; and Stage 5: 8.05km.h^{-1} at 18% grade.

The variables measured during the test were:

HR (beats.min^{-1}) was measured at the end of each stage (i.e. 2:45-3:00) and the HRmax was measured at the point of termination owing to exhaustion.

VO_2 (ml.kg^{-1}.min^{-1}, L.min^{-1}, STPD) and RER were measured continuously during each minute of exercise.

VO_2max ($ml.kg^{-1}.min^{-1}$) and RERmax was measured at the point of volitional test termination owing to exhaustion.

Differentiated (leg and chest) RPE and undifferentiated (overall) RPE were measured between 2:30-2:45 of each stage. (Note: For purpose of the present investigation, only RPE-overall was used in the statistical computations.)

Cumulative pedometer step count was recorded at the end of each stage i.e. every 3 minutes. At test termination, total pedometer step count for the entire test protocol was also recorded.

HR ($beats.min^{-1}$) was measured with a Polar Monitoring System (Woodbury, NY). An open-circuit respiratory-metabolic system (True Max 2400, Parvo Medics, Salt Lake City, UT) was used to measure VO_2 and compute RER. RPE- overall, RPE-legs and RPE-chest were measured using the Child OMNI-Walk/ Run Scale. The test was volitionally terminated by the subject owing to exhaustion and/or for any other reasons as determined by the subject.

During the treadmill test 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. At the end of the warm-up phase, the pedometer was reset to zero. The cumulative step count was obtained at the end of each stage and at termination of the treadmill session. The subjects were not informed of their pedometer step counts during the exercise session.

The PAI was calculated for each treadmill exercise stage. The PAI was calculated by multiplying cumulative pedometer step count and RPE-overall for that stage. Example: PAI for the second stage was calculated as follows:

PAI for 2^{nd} stage = Cumulative step count (step count for stage 1+ step count for stage 2) x RPE-overall for stage 2

PAI_{total} was calculated by multiplying total step count and the momentary RPE-overall measured at the point of termination of test:

PAI_{total} = Total step count x RPE-overall at test termination.

Kcal expenditure for each minute was determined using VO_2 measures and the RER. The Kcal expenditure was calculated by converting VO_2 ($L.min^{-1}$) to Kcal with adjustment for differential substrate utilization using the calculated RER (24; Appendix A). Cumulative Kcal for each stage was calculated by adding all three $Kcal.min^{-1}$ values in that stage and the total Kcal of previous stage(s). An example the cumulative Kcal calculated for 2^{nd} stage was as follows:

Cumulative Kcal 2^{nd} stage = Kcal 1^{st} stage + Kcal for 2^{nd} stage where:

Kcal 1^{st} stage = $Kcal.min^{-1}$ for minute1+ $Kcal.min^{-1}$ minute2+ $Kcal.min^{-1}$ for minute3

Kcal for 2^{nd} stage = $Kcal.min^{-1}$ for minute4+ $Kcal.min^{-1}$ for minute5+ $Kcal.min^{-1}$ for minute6

Total Kcal expenditure was the minute-by-minute accumulation of Kcal expenditure for the entire maximal exercise test. It was calculated by adding all the $Kcal.min^{-1}$ values for each subject:

Total Kcal = $\sum$ $Kcal.min^{-1}$ for entire treadmill test.

3.2.3 RPE-session

After termination of the treadmill exercise test, the subject was immediately seated for 5 minutes. The subject was seated in the treadmill testing room and drinking water was provided. The investigator was present and no reading or visual materials were provided. The investigator did not reveal any information regarding test responses. At the conclusion of the 5 minute post-test period a RPE-session (overall) was determined by asking the question “Please rate the level of exertion for your overall body that you felt for the entire exercise session”. RPE-session is a measure of perceived exertion experienced for an entire exercise session but estimated post-exercise following a priori defined period of rest (71).

The PAI (session) was calculated for the entire treadmill exercise bout. The PAI (session) was calculated by multiplying total pedometer step counts and RPE-session.

PAI (session) = Total step counts x RPE-session

3.2.4 Physical Activity Questionnaire

The Physical Activity Questionnaire (Appendix C, Appendix D) was administered following completion of the maximal treadmill test. This questionnaire was developed by Aaron et al. in 1993 to assess physical activity behavior in adolescents (1). This questionnaire was adapted from the Pima Physical Activity Questionnaire and Youth Risk Surveillance System questionnaire. The questionnaire measured physical activity, leisure-time activity and inactivity (1,2,28). The questionnaire was previously modified for use with the biracial population of the City of Pittsburgh (PA) School District (1). It is a valid tool for assessing habitual physical activity patterns in biracial pediatric population sub-sets (1,2).

Subjects responded to four multiple choice questions that measured the days of “hard exercise” and “easy exercise”, hours of screen time per day, and competitive athletic participation for the past 12 months. The hours of screen time per day was used to measure sedentary behavior. In addition, leisure time physical activity was also measured. From the list of physical activities participant recalled the activities in which they participated at least 10 times over the past year. If participant participated in an activity that was not listed, it was added to the list. Further detailed information regarding the frequency and duration of each activity in the past year was collected. An estimate of hours per week ($hrs.wk^{-1}$) of each leisure time activity was calculated and then the hours per week for all the activities were summed to derive an overall leisure physical activity estimate averaged over the past year (1,2):

$$\text{Hrs.wk}^{-1}\text{ of activity} = \frac{(\#\text{months.yr}^{-1})\text{x}(4.3\text{wks.month}^{-1})\text{x}(\#\text{days.wk}^{-1})\text{x}(\#\text{mins.day}^{-1})}{(60\text{mins.hr}^{-1})\text{x}(52\text{wks.yr}^{-1})}$$

$$\text{Total leisure time physical activity for the past year} = \sum \text{hrs.wk}^{-1}\text{ of activity}$$

3.3 STATISTICAL ANALYSIS

All data analyses were performed using SPSS statistical software (IBM SPSS statistics 20.0 for Windows, IBM Corp., Armonk, NY). The level of significance was set *a priori at* $p \leq 0.05$. Initially, the descriptive data was analyzed by calculating mean, standard deviation, range, and tests for normal distribution. Analyses 1, 2, and 3 were conducted using the 49 subjects who had step count data available for each treadmill stage. Analyses 4 and 5 used the 49 subjects identified above plus 35 subjects for whom only total test step count data was available i.e. N=84. Analyses 4 and 5 used a PAI (session) that was calculated using total step count for the entire protocol.

1. The concurrent validity of the PAI was examined using Pearson correlation and repeated measures regression analyses that express PAI as a function of both VO_2 and HR (N=49) during a load incremented maximal treadmill protocol in female and male children and adolescents ages 8-17 yr.

2. Linear regression analysis was employed to estimate cumulative Kcal expenditure using PAI (N=49) as the predictor variable.
3. Multiple linear regression analysis was performed with total Kcal expenditure as the criterion variable and PAI_{total}, age, height, weight, BMI, BMI percentile, HRmax, VO_2max, RERmax, leisure time physical activity and sedentary behavior (N=49) as predictor variables.
4. Linear regression analysis was employed to develop a statistical model to estimate total Kcal expenditure using PAI (session) (N=84) as the predictor variable.
5. Multiple linear regression analysis was performed with total Kcal expenditure as the criterion variable and PAI (session), HRmax, and VO_2max as predictor variables for children and adolescents (8-17 yr) performing load incremented treadmill exercise.

3.4 POWER ANALYSES

Power analysis was conducted to determine sample size based on the ability to detect significant interactions within the regression analysis. 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 12 subjects were required for statistical analyses 1,2, and 4. For statistical analyses 1 and 2, we had 49subjects'data and for statistical analysis 4 data of 84subjects were available. In addition, for multiple regression analysis i.e. statistical analyses 3 and 5 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 26 subjects were required. As such, data for49 subjects' data were available for statistical analysis 3 and data for 84 subjects were available for statistical analysis 5.

4.0 RESULTS

The primary purposes of this investigation were (a) to examine the validity of the PAI,(b) to develop a statistical model to predict cumulative Kcal expenditure using PAI as the predictor variable and (c) to develop a statistical model to predict total Kcal expenditure using PAI_{total} and selected physiological and behavioral measures as the predictor variables for children and adolescents performing load incremented maximal treadmill exercise. The secondary purpose of the study was to develop a prediction model to estimate total Kcal expenditure using the PAI (session) alone and in combination with selected physiological measures as the predictor variables.

The subjects (n=84) underwent a maximal treadmill exercise test. During treadmill testing HR, VO_2, pedometer step counts, and RPE were measured. The caloric expenditure for each treadmill stage was subsequently calculated using respiratory metabolic measures. Following maximal treadmill exercise, each subject completed a physical activity questionnaire. The questionnaire measured physical activity levels and sedentary behaviors in this pediatric population.

4.1 SUBJECT CHARACTERISTICS

Total step count data were available for all subjects in this study (N=84). A sub-group consisting of 49 subjects was identified from the primary pool of 84 subjects. These 49 subjects (male n=28, female n=21) also had pedometer step count data available for each stage of the treadmill test. The data for these 49 subjects were used for the statistical analyses where PAI and PAI_{total} were calculated using momentary RPE derived during each treadmill stage. The total test step count data for all 84 subjects were used to conduct statistical analyses involving the PAI (session).

Table 3. Descriptive characteristics of subjects

Number of participants	**N=49 (♂=28, ♀=21)**	**N=35 (♂=15, ♀=20)**	**N=84 (All subjects) (♂=43,♀=41)**
Age (yrs)	12.7±2.1	12.3±2.8	12.5±2.4
Height (cm)	160.0±12.7	156.6±17.6	158.6±14.9
Weight (Kg)	66.1±24.6	69.9±32.1	67.7±27.9
BMI ($Kg.m^{-2}$)	25.1±6.9	27.0±8.7	25.9±7.7
BMI percentile	78.9±21.2	84.4±19.9	81.2±20.8
Sedentary behavior($hrs.day^{-1}$)	3.2±1.7	3.0±2.1	3.1±1.9
Physical activity ($hrs.week^{-1}$)	7.4±6.4	6.5±5.5	7.0±6

Data are mean ± standard deviation. BMI: Body Mass Index.

Table 4. Exercise test responses

Number of participants	**N=49 (♂=28, ♀=21)**	**N=35 (♂=15, ♀=20)**	**N=84 (All subjects) (♂=43,♀=41)**
HRmax(beats.min^{-1})	192.0±13.9	193.4±16.3	192.6±14.9
Total kcal	61.2±24.9	61.6±27.4	61.3±25.8
RERmax	1.1±0.2	1.1±0.1	1.1±0.1
Total steps	976.9±297.0	886.9±244.8	939.4±277.7
RPE-session	6.6±1.8	6.7±2	6.6±1.9
PAI (session)	6466.2±2655.1	5902.3±2461.1	6231.26±2576.1
Total treadmill time(mins)	8.4±2	8.5±1.4	8.4±1.8
VO_2max(L.min^{-1})	2.2±0.7	2.2±0.9	2.2±0.8
VO_2max(mL.kg^{-1}.min^{-1})	35.6±9.9	33.4±8.5	34.7±9.4

Data are mean ± standard deviation. HRmax: Maximal heart rate; Kcal: Kilocalorie; RERmax: Maximal Respiratory Exchange Ratio; RPE: Rating of Perceived Exertion; PAI: Physical Activity Index; VO_2max (L.min^{-1} and mL.kg^{-1}.min^{-1}): Maximal oxygen uptake.

There was no statistical difference (p>0.05) between the three subject groups for any of the characteristics. Thus, all three groups were similar with respect to age, body composition, and cardiorespiratory fitness.

The subject characteristics were further stratified based on differences in BMI percentile. Subjects (n=84) were stratified as obese (BMI percentile 95 and above) and non-obese (BMI percentile below 95). This analysis was undertaken for descriptive purposes only and not used to examine the research problems.

Table 5. Descriptive characteristics of subjects based on BMI percentile classification

Body Weight Classification	Non-obese (n =48;♂=21,♀=27)	Obese (n=36;♂=22,♀=14)
Age (yrs)	11.9±2.8	13.3±1.5*
Height (cm)	152.6±15.8	166.5±8.9*
Weight (Kg)	48.9±15.7	92.8±19.4*
BMI (Kg.m^{-2})	20.3±3.1	33.3±5.4*
BMI percentile	70.1±21.6	95.9±0.2*
Sedentary behavior(hrs.day^{-1})	2.7±1.7	3.8±1.8*
Physical activity (hrs.week^{-1})	7.7±5.9	6.1±6

Data are mean ± standard deviation.* Difference between Non-obese and Obese ($p<0.05$).

Table 6.Exercise test responses of subjects based on BMI percentile classification

Body Weight Classification	Non-obese (n =48;♂=21,♀=27)	Obese (n=36;♂=22,♀=14)
HRmax(beats.min^{-1})	196.0±15.9	188.1±12.2*
Total kcal	57.6±27.1	66.3±23.5
RERmax	1.1±0.1	1.1±0.1
Total steps	1043.6±278.5	800.6±212.4*
RPE-session	6.7±1.7	6.5±2.1
PAI (session)	6948.2±2553.4	5275.4±2310.3*
Total treadmill time(mins)	9.1±1.8	7.5±1.3*
VO_2max(L.min^{-1})	2.0±0.7	2.4±0.8*
VO_2max(mL.kg^{-1}.min^{-1})	39.9±7.2	27.7±7.1*

Data are mean ± standard deviation.* Difference between Non-obese and Obese ($p<0.05$).

The obese group was significantly ($p<0.05$) greater than the non-obese group for mean age, height, weight, BMI, BMI percentile, VO2max (L.min^{-1}), and sedentary behavior. In comparison to the obese group, the HRmax, VO_2max (mL.kg^{-1}.min^{-1}), total steps, PAI (session), and total treadmill time values were significantly ($p<0.05$) higher for the non-obese group. There was no significant ($p<0.05$) difference between the obese and non-obese groups for total Kcal expenditure, RERmax, RPE-session, and physical activity levels.

4.2 CONCURRENT VALIDITY OF PAI

The concurrent validity analysis was conducted using the 49 subjects for whom step count data were available at each treadmill stage. The PAI for each stage was calculated by multiplying cumulative pedometer step count and momentary RPE-overall for a given stage. A multiple repeated measures regression analysis was carried out to examine the concurrent validity of the PAI using measured VO_2 (ml.kg^{-1}.min^{-1}), VO_2 (L.min^{-1}), and HR (beats.min^{-1}) as criterion variables. The regression analyses (Fig.3 and 4) demonstrated a significant ($p<0.05$) positive correlation between PAI and VO_2in mL.kg^{-1}.min^{-1}(r=0.725) and VO_2in L.min^{-1}(r=0.607). The HR also correlated significantly (r=0.755,$p<0.05$) with PAI (Fig.5). These results established the concurrent validity of the PAI during a load incremented maximal treadmill protocol in female and male children and adolescents ages 8-17 yr.

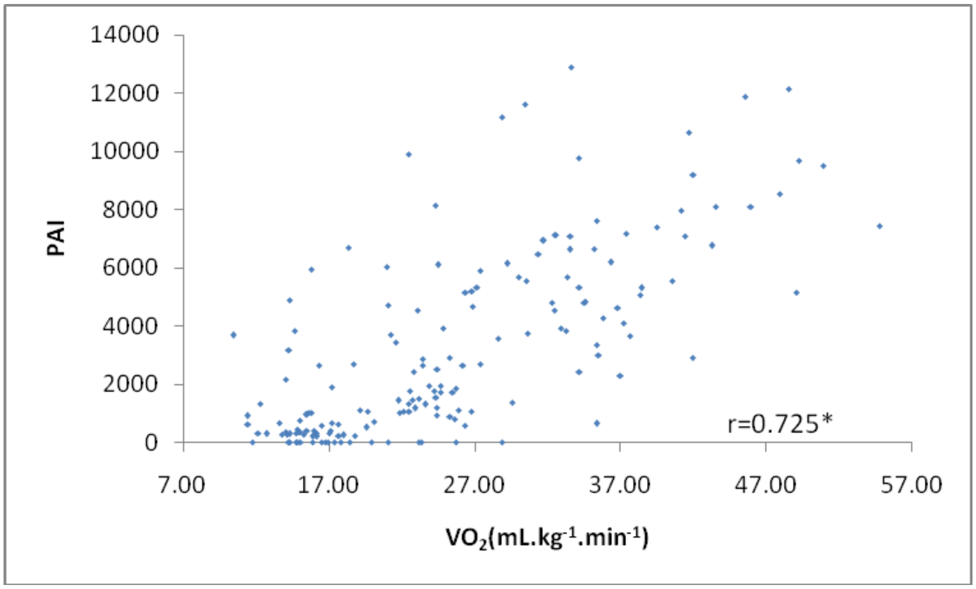

Figure 3. Regression analyses for relation between PAI and VO_2(mL.kg^{-1}.min^{-1})obtained for each stage of the treadmill test. *p<0.05

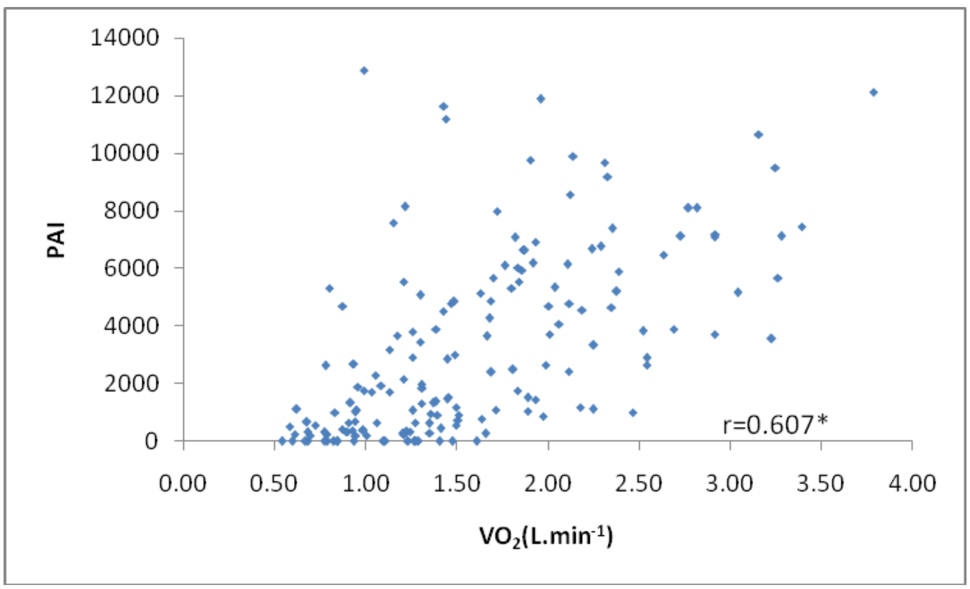

Figure 4. Regression analyses for relation between PAI and VO_2(L.min^{-1}) obtained for each stage of the treadmill test. *p<0.05

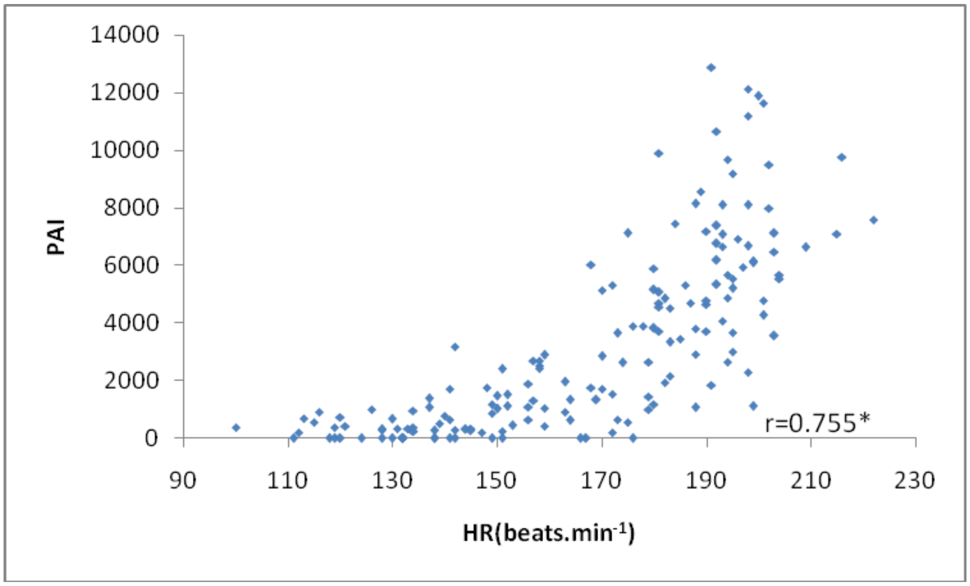

Figure 5.Regression analyses for relation between PAI and HR (beats.min^{-1}) obtained for each stage of the treadmill test. *p<0.05

4.3 CUMULATIVE KCAL PREDICTION MODEL

A statistical equation to estimate cumulative Kcal expenditure was developed using the PAI as the predictor variable. This prediction equation was developed using responses from the 49 subjects whose per stage step count data were available. A summary of the regression analysis for the cumulative kcal prediction model is presented in Table 7. The regression coefficient for the model was r = 0.736. The r^2 of 0.542 indicated that 54.2% of the variance in cumulative Kcal expenditure during load incremented treadmill testing was explained by the children's PAI. The results of the ANOVA indicated that the observed r^2value was significantly greater than would be expected due to chance alone. The model to predict cumulative Kcal was:

Model I : Cumulative Kcal = 21.632 + 0.006 (PAI).

The PAI was calculated by multiplying cumulative pedometer step count and momentary RPE-overall for a given stage

Table 7. Prediction Model I for cumulative Kcal: summary of regression analysis

Step	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.736	0.542	0.539	17.587	0.542	193.978	0.000

1. Predictors: (Constant), PAI

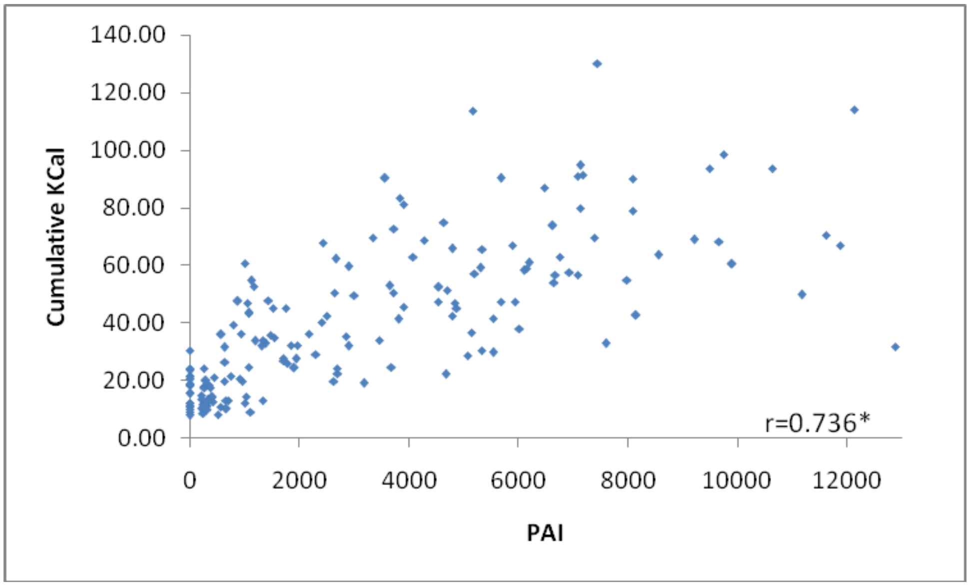

Figure 6.Relation between cumulative Kcal expenditure and PAI. *p<0.05

4.4 TOTAL KCAL PREDICTION MODEL

4.4.1 Multivariate Model: PAI_{total} and selected physiological and behavioral predictor variables

A summary of the stepwise regression analysis to estimate total Kcal expenditure using both the PAI_{total} and selected physiological and behavioral predictor variables is presented in Table 8. The variables selected by the stepwise regression analysis for inclusion in the total Kcal prediction model were: (a) PAI_{total} and (b) VO_2max ($L.min^{-1}$). The regression coefficient for the model was r=0.872. The r^2 of 0.76 indicated that 76% of the variance in total Kcal expenditure was explained by PAI_{total} and VO_2max ($L.min^{-1}$) for children performing a load incremented treadmill protocol. The multiple regression selected VO_2max ($L.min^{-1}$) as a predictor variable on the first step and PAI_{total} on the second step of the model (Table 8). The results of the ANOVA indicated that the r^2 was significantly greater than would be expected due to chance alone. Of the remaining pool of potential predictor variables {age, height, weight, BMI, BMI percentile, HRmax, VO_2max ($ml.kg^{-1}.min^{-1}$), RERmax, leisure time physical activity and sedentary behavior}, none significantly increased the proportion of explained variance in total Kcal once PAI_{total} and VO_2max ($L.min^{-1}$) were in the model.

The model to predict total Kcal was:

Model II :Total Kcal = $-11.59+0.002(PAI_{total})+27.245(VO_2max)$.

Total Kcal expenditure was determined as the cumulative Kcal expenditure for the entire duration of the maximal treadmill exercise test. It was calculated for each subject by adding all the $Kcal.min^{-1}$ values for the entire treadmill test. The PAI_{total} was calculated by multiplying total step count and the RPE-overall measured at the termination of the treadmill test. The VO_2max ($L.min^{-1}$) was measured at the point of volitional test termination owing to exhaustion.

Table 8. Prediction Model II for total Kcal: summary of multiple regression analysis

Step	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.848	0.719	0.713	13.356	0.719	115.162	0.000
2	0.860	0.739	0.734	15.367	0.203	80.029	0.000

1. Predictors: (Constant), VO_2max ($L.min^{-1}$)
2. Predictors: (Constant), VO_2max ($L.min^{-1}$), PAI_{total}

Coefficients for Model II

Step		Unstandardized Coefficients*		Significance
		B	Std. Error	
1	Constant	-3.57	6.257	0.571
	VO_2max ($L.min^{-1}$)	29.396	2.739	0.000
2	Constant	-11.59	6.531	0.083
	VO_2max ($L.min^{-1}$)	27.245	2.675	0.000
	PAI_{total}	0.002	0.001	0.009

* Criterion Variable: Total Kcal

In Model II the strongest predictor of total Kcal expenditure was VO_2max ($L.min^{-1}$). As such, in order to mitigate the impact of maximal aerobic power, VO_2max ($mL.kg^{-1}.min^{-1}$, $L.min^{-1}$) was dropped as a predictor variable in a subsequent stepwise regression analysis while retaining the remaining physiological and behavioral variables. A summary of this follow-on stepwise regression analysis for the total Kcal expenditure using both the PAI_{total} and selected physiological and behavioral predictor variables is presented in Table 8. The variables selected by the stepwise regression analysis for inclusion in the follow-on model to predict total Kcal were: (a) PAI_{total} and (b) height (cm). The regression coefficient for the model was r=0.745. The r^2 of 0.56 indicated that 56% of the variance in the total Kcal expenditure was explained by PAI_{total} and height for children performing a load incremented treadmill protocol. The multiple regression selected height as a predictor on the first step and PAI_{total} on the second step of the model (Table 9). The results of the ANOVA indicated that the r^2 for the two step model was significantly greater than would be expected due to chance alone. Of the remaining pool of potential predictor variables (age, height, weight, BMI, BMI percentile, HRmax, RERmax, leisure time physical activity and sedentary behavior), none significantly increased the proportion of explained variance in total Kcal once height and PAI_{total} entered the model.

The model to predict total Kcal was:

Model III : Total Kcal = -151.87+0.004(PAI_{total})+1.176(Height).

Table 9. Prediction Model III for total Kcal excluding maximal oxygen uptake: summary of multiple regression analysis

Step	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.626	0.392	0.378	19.647	0.392	29.012	0.000
2	0.745	0.555	0.535	16.992	0.163	16.166	0.000

1. Predictors: (Constant), Height
2. Predictors: (Constant), Height, PAI_{total}

Coefficients

Step		Unstandardized Coefficients*		Sig.
		B	Std. Error	
1	Constant	-135.487	36.451	0.001
	Height	1.225	0.227	0.000
2	Constant	-151.868	31.786	0.000
	Height	1.176	0.197	0.000
	PAI_{total}	0.004	0.001	0.000

* Criterion Variable: Total Kcal

Finally, a regression analysis was employed to examine the influence of PAI_{total} alone as a predictor of total Kcal expenditure and the results are presented in table 10. The model for predicting total Kcal was:

Model IV : Total Kcal = 34.924+0.004(PAI_{total}).

Table 10. Prediction Model IV for total Kcal using PAI_{total} as a predictor variable: summary of regression analysis

Step	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.437	0.191	0.174	22.656	0.191	11.097	0.002

1. Predictors: (Constant), PAI_{total}

Coefficients

Step		Unstandardized Coefficients*		Sig.
		B	Std. Error	
1	Constant	34.924	8.512	0.000
	PAI_{total}	0.004	0.001	0.002

* Criterion Variable: Total Kcal

4.4.2 PAI (session) as a predictor variable

A statistical model to estimate total Kcal expenditure for the entire exercise session was developed using the PAI (session) as the predictor variable. This prediction equation was developed using the 84 children who comprised the primary subject pool. A summary of the regression analysis for the total Kcal prediction model is presented in Table 11. The regression coefficient for the model was r = 0.363. The r^2 of 0.132 indicated that 13.2% of the variance in total Kcal was explained by the PAI (session). The results of the ANOVA indicated that the r^2 value was significantly greater than would be expected due to chance alone. The model to predict total Kcal was:

Model V : Total Kcal = 38.643 + 0.004(PAIsession).

PAI (session) was calculated by multiplying the total pedometer step count for the entire exercise protocol and RPE-session (overall). Total Kcal expenditure was the accumulated Kcal expenditure for the entire duration of maximal exercise test. It was calculated by adding all the $Kcal.min^{-1}$ values for each subject:

Total Kcal = $\sum Kcal.min^{-1}$.

Table 11. Prediction Model V for total Kcal: summary of regression analysis

Step1	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.363[a]	0.132	0.121	24.23	0.132	12.447	0.001

a. Predictors: (Constant), PAI (session)

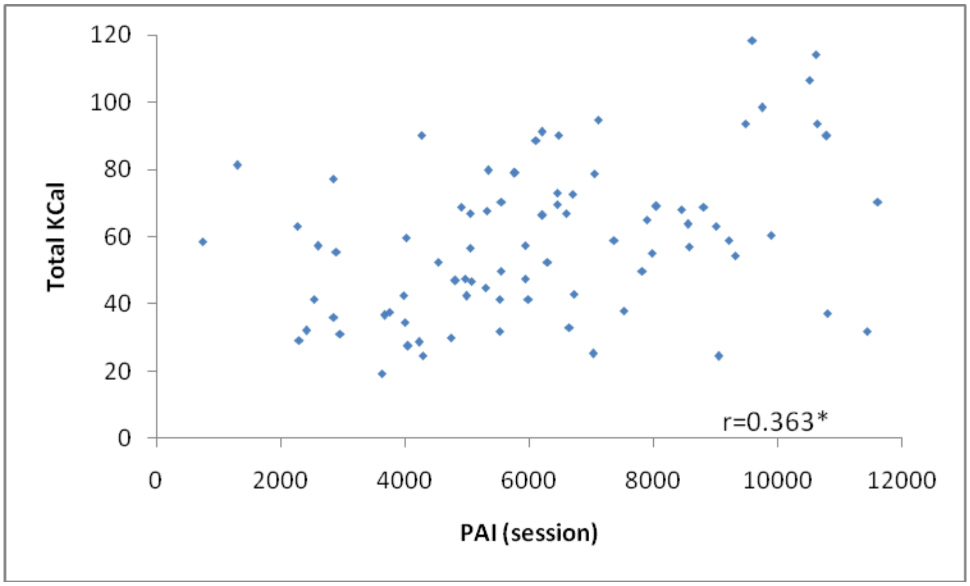

Figure 7.Relation between total Kcal expenditure and PAI (session). *p<0.05

4.4.3 Multivariate model: PAI (session) and selected physiological predictor variables

A summary of the stepwise regression analysis to estimate total Kcal expenditure using both the PAI (session) and selected physiological predictor variables is presented in Table 12. The variables selected by the stepwise regression analysis for inclusion in the total Kcal prediction model were PAI (session), VO_2max ($L.min^{-1}$), and HRmax ($beats.min^{-1}$). The regression coefficient for the model was r=0.918. The r^2 of 0.842 indicated that 84.2% of the variance in total Kcal expenditure was explained by PAI (session), VO_2max ($L.min^{-1}$), and HRmax for female and male children performing a load incremented treadmill protocol. The multiple regression selected VO_2max ($L.min^{-1}$) on the first step of the model, HRmax on the second step, and PAI (session) on the third step (Table 12). The results of the ANOVA indicated that the r^2 value at each step of the model was significantly greater than would be expected due to chance alone. The remaining potential predictor variable VO_2max ($ml.kg^{-1}.min^{-1}$), did not significantly increase the proportion of explained variance in total Kcal once PAI (session), VO_2max ($L.min^{-1}$), and HRmax were in the model.

The model to predict total Kcal was:

Model VI : Total Kcal = -64.76+0.001(PAIsession)+26.998(VO_2max)+0.305(HRmax).

The PAI (session) was calculated by multiplying total pedometer step counts and RPE-session for the entire exercise session. The VO_2max ($L.min^{-1}$) and HRmax ($beats.min^{-1}$) were measured at the point of volitional test termination owing to exhaustion.

Table 12. Prediction Model VI for total Kcal using PAI (session) and selected physiological variables: summary of multiple regression analysis

Step	R	R Square	Adjusted R Square	Std. Error of Estimate	R Square Change	F Change	Sig. of F Change
1	0.883	0.780	0.777	12.194	0.78	290.791	0.000
2	0.908	0.825	0.820	10.952	0.045	20.642	0.000
3	0.918	0.842	0.836	10.455	0.018	8.892	0.004

1. Predictors: (Constant), VO_2max ($L.min^{-1}$)
2. Predictors: (Constant), VO_2max ($L.min^{-1}$), HRmax
3. Predictors: (Constant), VO_2max ($L.min^{-1}$), HRmax, PAI (session)

Coefficients

Model		**Unstandardized Coefficients***		**Significance**
		B	**Std. Error**	
1	Constant	0.278	3.820	0.942
	VO_2max ($L.min^{-1}$)	28.116	1.649	0.000
2	Constant	-70.076	15.861	0.000
	VO_2max ($L.min^{-1}$)	27.886	1.482	0.000
	HRmax	0.368	0.081	0.000
3	Constant	-64.759	15.245	0.000
	VO_2max ($L.min^{-1}$)	26.998	1.446	0.000
	HRmax	0.305	0.080	0.000
	PAI (session)	0.001	0.000	0.004

* Criterion Variable: Total Kcal

4.5 SUMMARY OF RESULTS

The primary data set included 84 subjects all of whom had total step count data available. A sub-group consisting of 49 subjects was then identified from the primary pool of 84 subjects. In addition to the total step count data, these 49 subjects had pedometer step count data available for each stage of the treadmill test. The data for these 49 subjects were used to establish concurrent validity and to develop prediction Model I and II. The dataset derived from all 84 subjects was used to develop the statistical Model V and VI. See Table 13 for a summary of Models I, II, V, and VI.

Table 13. Summary for prediction models

Model No.	Criterion Variable	SEE	r	r^2
I	Cumulative Kcal	17.59	0.74	0.54
II	Total Kcal	15.37	0.87	0.76
V	Total Kcal	24.23	0.36	0.13
VI	Total Kcal	10.46	0.92	0.84

The concurrent validity of the PAI was established using VO_2 and HR as the criterion variables. Multiple regression analyses revealed a strong, positive relation between the PAI score and VO_2in $L.min^{-1}$($r=0.607$, $p<0.05$), VO2 in $mL.kg^{-1}.min^{-1}$($r=0.725$, $p<0.05$) and HR in $beats.min^{-1}$ ($r=0.755$, $p<0.05$).

Model I was developed to predict cumulative Kcal expenditure using PAI as a predictor variable:

Model I : Cumulative Kcal = 21.632 + 0.006(PAI) p<0.05, SEE=17.59, r=0.74, r^2=0.54.

The PAI_{total} and selected physiological and behavioral variables were used to develop a prediction Model (II) to estimate total Kcal expenditure. The variables selected by the stepwise regression analysis for inclusion in prediction Model II were PAI_{total} and VO_2max ($L.min^{-1}$):

Model II :Total Kcal =-11.59+0.002(PAI_{total})+27.245(VO_2max)

$p<0.05$, SEE=15.37, r=0.872, r^2=0.76.

Model I estimated cumulative kcal expenditure using only PAI as a predictor whereas Model II estimated kcal expenditure using PAI and VO_2max as predictors for female and male children 8-17 yr old performing a load incremented maximal treadmill protocol.

The prediction Model V was developed using the primary pool of 84 subjects. In Model V, the PAI (session) was used as a predictor variable to estimate total Kcal expenditure:

Model V : TotalKcal = 38.6 + 0.004(PAIsession), $p<0.05$, SEE=24.23, r=0.36, r^2=0.13.

The PAI (session) was also combined with selected physiological variables to develop a prediction Model VI to estimate total Kcal expenditure. The variables selected by the stepwise regression analysis for inclusion in prediction Model VI were VO_2max ($L.min^{-1}$), HRmax, and PAI (session):

Model VI :Total Kcal = -64.759+26.998(VO2max)+0.305(HRmax)+0.001 (PAI (session)$p<0.05$, SEE=10.46, r = 0.918 , r^2 = 0.842.

5.0 DISCUSSION

The primary purposes of this investigation were, (a) to examine the validity of the PAI,(b) to develop a statistical model to estimate cumulative Kcal expenditure using the PAI score as the predictor variable and (c) to develop a statistical model to estimate total Kcal expenditure using PAI_{total} and selected physiological and behavioral variables as the predictors for children and adolescents performing load incremented maximal treadmill exercise. The secondary purpose of the study was to develop a prediction model to estimate total Kcal expenditure using the PAI (session) alone and in combination with selected physiological variables as the predictors.

5.1 SUBJECT CHARACTERISTICS

Total step count data were available for all subjects in this investigation (N=84). A sub-group consisting of 49 subjects was identified from the primary pool of 84 subjects. These 49 subjects also had pedometer step count data available for each stage of the treadmill test. The data for these 49 subjects were used in the initial three statistical analyses. In these analyses, PAI was calculated using momentary RPE and step count for each treadmill stage. The total sample of 84 subjects that comprised the primary subject pool was used to conduct the statistical analysis involving the PAI (session). The first step in data reduction and analyses was to determine that the descriptive characteristics of the sub-group comprised of 49 subjects did not differ from the remaining 35 individuals in the primary subject pool. The data analysis demonstrated that there was no difference among these two subject sub-groups in age, body composition, aerobic fitness, HRmax, RPE-session, PAI (session), total treadmill exercise time, physical activity level, and sedentary behavior.

The total subject pool (N=84) was also stratified based on BMI percentile. As noted previously, this stratification was done for descriptive purposes only and not to explain or generalize the primary findings. Subjects were stratified as obese (BMI percentile of 95 and above) and non-obese (BMI percentile below 95). This is a common method to classify body composition of children where obesity or overweight is of interest (7). As expected, the obese group was significantly ($p<0.05$) higher than the non-obese group for mean bodyweight, BMI, and BMI percentile. The mean age and height of the obese group was also greater than the non-obese group. Comparatively higher bodymass is associated with increased metabolic demand during locomotor activities, likely explaining the significantly higher VO_2max observed for the obese group when values were expressed in L.min^{-1}. However, when VO_2max was indexed to total body weight (i.e. VO_2max inmL.kg^{-1}.min^{-1}), maximal aerobic power was significantly ($p<0.05$) higher for the non-obese than obese group. Thus, when compared to the obese group the non-obese group was more aerobically fit. The leisure time physical activity levels were higher for the non-obese than obese group and the non-obese group reported less sedentary behavior. Therefore, the comparatively higher aerobic fitness level (VO_2max in mL.kg^{-1}.min^{-1}) was generally consistent with daily patterns of greater physical activity and fewer sedentary pursuits in the non-obese subjects.

As noted above, VO_2max in L.min^{-1}was significantly higher ($p<0.05$)for the obese than non-obese group. However, there was no significant difference ($p<0.05$) between the obese and non-obese group for total Kcal expenditure during the load incremented treadmill protocol. The reason for the similarity in total Kcal expenditure between groups may be that the obese subjects were on average taller than the non-obese group. Greater body height is typically associated with longer leg length. Thus, a given treadmill speed is accomplished using comparatively fewer strides per minute, i.e. steps. The fewer steps per minute resulted in less vertical displacement of the body's center of mass requiring less energy to perform a given treadmill speed. The result was a similar total Kcal expenditure for the obese and non-obese subjects despite a higher absolute VO_2max ($L.min^{-1}$) in the heavier group.

The non-obese sub-group achieved the same mean RERmax as the obese group, but at a higher HRmax and greater total treadmill exercise time. Thus, the non-obese group demonstrated comparatively better maximal treadmill exercise performance.

5.2 CONCURRENT VALIDITY OF THE PAI

One of the purposes of this investigation was to establish concurrent validity of the PAI during a load incremented maximal treadmill protocol performed by female and male children and adolescents ages 8-17 yrs. The PAI for each stage was calculated by multiplying cumulative pedometer step count and RPE-overall for a given stage. Measured VO_2 ($ml.kg^{-1}.min^{-1}$ and $L.min^{-1}$) and HR ($beats.min^{-1}$) were used as criterion variables to establish the concurrent validity of the PAI. It was hypothesized that the PAI score would increase concurrently with increases in VO_2 and HR as treadmill exercise intensity increased. The findings supported this hypothesis, providing validity evidence for use of the PAI by children and adolescents performing load incremented aerobic exercise.

The PAI is proposed as a valid indicator of total load (volume x intensity) for most types of locomotor exercise. The PAI score takes into consideration both volume and intensity of a given locomotor activity. As the volume and intensity of aerobic exercise increases the PAI score is also expected to increase. In the present investigation, the volume of activity was measured by pedometer step count and the relative exercise intensity was measured by RPE-overall. The increase in steps per minute (volume) resulted in increased vertical displacement of the center of body mass, placing greater demand on the cardiorespiratory and aerobic-metabolic systems. The increase in VO_2 and HR as a function of progressively increasing exercise load mediated a corresponding increase in relative perceptual intensity as evidenced by concurrent increases in RPE-overall. Taken together (i.e. steps x RPE-overall) the increase in the PAI score occurred in direct correspondence with an increase in total exercise volume during graded treadmill testing for the children/adolescents studied.

Increases in physiological mediators (VO_2, HR) during most forms of aerobic exercise are associated with a corresponding increase in RPE (141). Borg's Effort Continua Model proposes that the responses to exercise can be described by inter-related physiological, perceptual, and performance continua. As the intensity of exercise performance increases, there is a corresponding and interdependent change in both the perception of physical exertion and associated physiological responses. This linkage indicates that perceptual responses (i.e. RPE) can provide much the same information concerning the intensity of the exercise performance as do physiological (i.e. HR and VO_2) responses (22,116,141). In a conceptually similar manner, as the PAI score increased during the load incremented treadmill protocol, VO_2 and HR increased concurrently for the pediatric subset that was studied.

The significant ($p<0.05$) positive correlation between the PAI score and VO_2 in $mL.kg^{-1}.min^{-1}$(r=0.725), VO_2in $L.min^{-1}$(r=0.607), and HR(r=0.755) established concurrent validity for the 8-17 year old female and male children/adolescents that were studied. During a load incremented maximal treadmill protocol, the PAI score increased concurrently as the cardiorespiratory and aerobic metabolic demands increased. These findings provided physiological validity evidence for the PAI as a measure of the total activity load (i.e. volume x intensity) during maximal treadmill exercise involving children and young adolescents. These results supported the hypothesis that the PAI would demonstrate significant positive correlations with $VO_2$and HR responses for children and adolescents (8-17 year old) during a load incremented maximal treadmill protocol

There are three published studies pertaining to the PAI (93,176,178). The initial study did not report concurrent validity of the PAI, but determined a significant positive correlation (r=0.69) between PAI and Kcal expenditure for recreationally active college age (23 yr) male and female subjects (176).The second study examined the validity of the PAI in estimating Kcal expenditure during submaximal treadmill exercise performed by recreationally active college-aged (20 yr) females. The concurrent validity of the PAI was established using VO_2(r=0.91) and HR (r=0.85) as criterion variables.

The above two studies pertaining to the PAI were conducted using college age, recreationally active males and females (176,178). The third study investigated the relation between the PAI and energy expenditure (r=0.16 to 0.44) in children (93). However, there is no published research on the validity of the PAI for use in a pediatric population, where cardiorespiratory variables such as VO_2 and HR were employed as criterion variables. The present investigation is the first study that established concurrent validity of the PAI among children and adolescent (8-17yr) during load incremented maximal treadmill exercise.

5.3 CUMULATIVE KCAL PREDICTION MODEL

One of the purposes of this study was to develop a statistical model to estimate cumulative Kcal expenditure using the PAI score as the predictor variable. The regression equation used responses from the 49 subjects whose per stage step count data were available. Model I as presented below estimated cumulative Kcal expenditure for load incremented treadmill exercise using PAI scores of children and adolescents age 8 to 17 yrs:

Model I : Cumulative Kcal = 21.632 + 0.006(PAI)p<0.05, SEE=17.59, r=0.74, r^2=0.54.

The model demonstrated a positive and statistically significant correlation (r = 0.736) between PAI score and cumulative kcal expenditure during load incremented treadmill exercise. The PAI score for the pediatric sample that was studied explained 54.2% of the variance in kcal expenditure for load incremented treadmill exercise. These results supported the hypothesis that a statistical model using the PAI as a predictor variable would explain significant variance in cumulative Kcal expenditure for 8-17 yr old female and male children and adolescents performing a load incremented maximal treadmill protocol.

The statistical model that employed the PAI score to estimate kcal expenditure used a multiplicative format consisting of a measure of activity volume (i.e. step count) and relative exercise intensity (i.e. RPE-overall). During the treadmill exercise test as the graded exercise load progressed, the number of steps per minute also increased. The increased steps per minute resulted in greater vertical displacement of the center of body mass. This progressively greater rate of body mass displacement required correspondingly more energy to perform the exercise load. Therefore, the increase in Kcal expenditure was a result of increased aerobic metabolic demand owing to a greater number of steps required as the treadmill grade and speed increased. In addition, as the exercise load progressed on a stage-by-stage basis, there was a corresponding increase in RPE-overall. RPE-overall is in part driven by the relative aerobic metabolic demand of the exercise task. As noted in the research rationale, RPE-overall is used as the intensity component of the calculated PAI. Therefore, the relative perceptual intensity would be expected to contribute to the explained variance in locomotor energy expenditure. It follows that both volume (step counts) and intensity (RPE) combine to reflect the aerobic metabolic requirement of weight bearing aerobic exercise. It was found that the calculated PAI was a simple and effective statistical tool to predict energy expenditure during graded treadmill exercise. Based on the present findings, this conclusion is generalizable to 8-17 year old children/adolescents performing load incremented treadmill exercise terminating at maximal intensity.

There are three published studies that investigated the relation between the PAI and Kcal expenditure during locomotor activities. Using an intermittent treadmill protocol, positive correlations of r=0.69 (176) and r=0.86 (178) were observed between PAI score and Kcal expenditure among young recreationally active adult subjects. The only published study involving children reported correlation coefficients ranging from r=0.16 to 0.44 between PAI score and energy expenditure for students participating in physical education classes (93). The correlation values between PAI score and Kcal expenditure observed in the current investigation were much higher than in the previous pediatric study reported by Lagally et al. (93).

The current study employed a continuous incremental treadmill protocol. In contrast, previous studies of the PAI used a submaximal intermittent exercise test protocol administered under standardized laboratory conditions (176,178) or the research was conducted using free-form movement in a physical education class (93).It is proposed that the results observed in the current study are not entirely consistent with the above described previous studies (93,176,178) because exercise protocols were different between the studies. Weary et al. (176,178) and Lagally et al. (93) held duration constant but intensity varied during exercise protocols. The treadmill protocol employed in the current study increased exercise load using an incremental format. Likely owing in part to inter-individual differences in aerobic fitness the final exercise intensity and performance duration associated with this standardized protocol varied between subjects. Therefore, the total load varied across subjects in the current investigation. This limits the ability to compare the observed correlation coefficients between the PAI and total Kcal expenditure in the current study with those reported in previous studies (93, 176,178).

Of importance, is that the treadmill protocol employed in the current study increased exercise load using an incremental format. Because the treadmill protocol employed presently was incremental, the progressive loading may have contributed to a higher correlation between PAI score and measures of aerobic-metabolic demand than observed in previous investigations. This statistical result is commonly attributed to a protocol demand-bias, where anticipation of impending increases in exercise intensity influence momentary RPE responses that is, for each progressive treadmill stage, the preceding exertional level served as a perceptual reference point that subconsciously elevated the subsequent exertional rating. During the incremental protocol the subjects knew that the treadmill protocol intensity would increase every stage. This knowledge at least in part subconsciously shaped succeeding perceptual effort responses. Thus, the comparatively higher PAI validity correlations observed presently could have been partly due to the simultaneous increase in physical load and the associated subconscious expectation that exertional perceptions should also increase i.e. protocol demand-bias. Differences in the extent to which protocol demand-bias was encountered in previous PAI studies (93,176,178) and in the current study may in part account for the reported differences in PAI validity correlation coefficients.

5.4 TOTAL KCAL PREDICTION MODEL

5.4.1 PAI_{total} and selected physiological and behavioral predictor variables

One of the purposes of the present investigation was to develop a robust model to estimate total Kcal expenditure during load incremented exercise by using PAI_{total} in conjunction with selected physiological, anthropometric, and behavioral variables as statistical predictors. The PAI_{total} was calculated by multiplying total steps for the entire exercise session with the RPE-overall measured during the last stage of the treadmill exercise test. The regression equation was developed using responses from the 49 subjects whose per stage step count data were available. Besides PAI_{total}, other potential predictor variables included in the statistical analysis were age, height, weight, BMI, BMI percentile, HRmax, VO_2max (ml.kg^{-1}.min^{-1}), VO_2max (L.min^{-1}), RERmax, leisure time physical activity and sedentary behavior. The variables selected by the regression analysis for inclusion in Model II to predict total Kcal expenditure were PAI_{total} and VO_2max (L.min^{-1}). This prediction model estimated total Kcal expenditure for the entire load incremented treadmill exercise session as follows:

Model II :Total Kcal =-11.59+0.002(PAI_{total})+27.245(VO_2max)p<0.05, SEE=15.37, r=0.87, r^2=0.76.

The model demonstrated a positive and statistically significant correlation (r = 0.872) using responses derived from a pediatric sample performing a load incremented treadmill exercise test. The children's PAI_{total} and VO_2max ($L.min^{-1}$) explained 76% of the variance in total kcal expenditure for load incremented treadmill exercise terminating at maximal intensity. The correlation coefficient in this regressive model was higher than observed by Weary et al., where only the PAI was employed as a predictor variable (178).

The use of PAI_{total} to estimate kcal expenditure employs a multiplicative format consisting of a measure of activity volume (i.e. total step count) and relative intensity (i.e. RPE-overall). Because the calculated PAI_{total} represented the total work performed (volume x intensity), it provided an accurate and functional estimate of kcal expenditure of children performing incremental aerobic exercise.

Of the variables that entered Model II, VO_2max ($L.min^{-1}$) was the strongest predictor of total Kcal expenditure. Due to practical limitations in applying a model that included actual laboratory assessment of VO_2max, the measure of maximal aerobic power was dropped as a predictor variable in a follow-on regression analysis. The follow-on analysis produced a revised model that employed only PAI_{total} and height as predictors of total Kcal:

Model III :Total Kcal = -151.87+0.004(PAI_{total})+1.176(Height) p<0.05, SEE=16.992, r=0.745, r^2=0.555

The revised prediction model explained 56% of the variance in total Kcal expenditure during load incremented treadmill exercise. As the revised energy expenditure prediction model included only PAI_{total} and height, it was considered to be more practical for use with children/adolescents performing aerobic exercise of progressively increasing intensity.

The PAI is calculated as the product of pedometer step counts and RPE. Studies have shown that pedometers are most accurate in measuring steps taken , less accurate at estimating distance traveled and even less accurate at estimating energy expenditure of locomotion (17,18,70).Various studies using different systems to measure energy expenditure found the correlation between pedometer outputs and measured energy expenditure to range from r=0.46 to 0.88 (171).Gardner and Poehlman reported a significant correlation (r=0.61) between pedometer movement counts and measured energy expenditure over a 48 hour period using a doubly labeled water technique as the criterion measure (104). However, other studies failed to demonstrate statistically significant correlations between the same variables i.e. r= 0.26 to 0.42 (48,98).

Eston and Rowlands (42) observed a significant correlation (r=0.782) between VO_2 and step counts derived from a hip positioned pedometer during treadmill exercise in children. Weary et al. (178) reported that the variance explained by a statistical model to predict Kcal expenditure using a PAI score was comparatively greater for moderate than either low or high intensity exercise in young adults. There was a significant difference ($p<0.05$) between predicted and measured Kcal expenditure for both low and high intensity exercise bouts (178). For the current study, the treadmill protocol consisted of exercise intensities that progressed incrementally and continuously from low to maximal levels. As such, the possibility that the load incremented protocol produced a “demand bias” on RPE responses may in part have accounted for the comparative higher correlations observed presently.

Stone et al. (161) reported that accelerometer and pedometer movement counts provided the best estimation of energy expenditure at moderate treadmill speeds (r^2=0.48 to 0.96). The study by Stone et al. (161) also reported that the difference between measured and pedometer estimated energy expenditure increased as the subjects' (8-40 yrs) leg length increased. Also, the observed increase in prediction error in taller participants was exacerbated with increased treadmill speed for all statistical models that were employed (161). In the current study, it was observed that PAI_{total} and height were significant predictor variables in Model II. These results were similar to that observed by Stone et al. (161). Stone et al. (161) reported that height was a significant predictor of Kcal expenditure. Taller individuals usually have longer legs. As such, taller individuals can perform a given treadmill speed using fewer steps per minute. Fewer steps per minute resulted in less vertical displacement of the center of body mass, requiring lower Kcal expenditure to perform a given locomotor speed. As such, it would be expected that height would have a significant influence on energy expenditure during a locomotor activity such as graded treadmill exercise.

Both pedometers and accelerometers provide a valid measure of physical activity related movement (182). However, estimations of energy expenditure based on activity monitor counts are less accurate than when measured using indirect calorimetry or doubly labeled water techniques. In general, the activity monitors overestimate energy expenditure for high intensity activities and underestimate energy expenditure for low intensity activities (110). An additional problem related to the use of prediction equations that employ movement counts is that they assume steady-state aerobic metabolic responses over the observation time period, usually a one-minute interval. Consequently, such models do not account for rapid variations in exercise intensity when predicting energy expenditure (168). In general, physical activity monitors do not precisely differentiate between varying intensities of physical activity, especially locomotor movement. As such, energy expenditure estimations based on movement counts during locomotor activities can exhibit measurement error. The present investigation recognized that it is necessary to precisely account for the contribution of exercise intensity when developing a statistical model to predict Kcal expenditure of locomotion. The statistical models developed presently included a subjective measure of relative exercise intensity (RPE). The PAI score in this statistical model employed a multiplicative calculation involving both RPE (intensity) and pedometer step counts (volume). The model was expected to provide a strong estimation of energy expenditure during load incremented aerobic exercise for children and young adolescents. The high correlations between the PAI score and energy expenditure observed presently supported this hypothesis.

The behavioral variables (i.e. leisure time physical activity and sedentary behavior) that were included in the primary predictor pool did not contribute significantly to the explained variance in total Kcal expenditure. The behavioral variables were measured using a questionnaire developed by Aaron et al. (1) in 1993. The questionnaire was previously modified for use with the biracial population of the City of Pittsburgh (PA) School District (1). Previous studies reported that the Aaron et al. questionnaire is a valid and reproducible tool for assessing habitual physical activity patterns and inactive behaviors in biracial pediatric population sub-sets (1,2,28). However, neither physical activity levels nor measures of inactive behaviors assessed through this questionnaire were related to total Kcal expenditure of children/adolescents performing load incremented treadmill exercise in the present investigation.

5.4.2 PAI (session) as a predictor of energy expenditure

A statistical model to estimate total Kcal expenditure for the entire exercise session was developed using the PAI (session) as the predictor variable. The model was developed using all84 subjects as total step count data were available for each of these individuals. The PAI (session) was calculated by multiplying RPE-session and total steps for the entire exercise session:

Model V : TotalKcal = 38.6 + 0.004(PAIsession), $p<0.05$, SEE=24.23, $r=0.36$, $r^2=0.13$.

The model demonstrated a statistically significant but weak correlation coefficient ($r = 0.36$) using responses measured during load incremented treadmill exercise. The children's PAI (session) explained 13.2% of the variance in total Kcal expenditure for load incremented treadmill exercise. Even though the observed correlation value was weak, the proportion of explained variance was never-the-less statistically significant.

Herman et al. (175) reported that in adult subjects, RPE-session correlated significantly with $\%HR_{peak}$ ($r^2=0.74$), $\%VO_{2peak}$ ($r^2=0.76$), and $\%HR_{reserve}$ ($r^2=0.71$). There are no published studies available that employed RPE-session separately or as a component of PAI (session) to estimate VO_2 and/or Kcal expenditure in children and adolescents during physical activity. Previous studies using a number of different measurement systems to determine energy expenditure reported that correlations between pedometer outputs and measured energy expenditure ranged from r=0.46 to 0.88 (171). In comparison to previously reported pedometer studies, the power of the model to predict Kcal expenditure using the PAI (session) in the current study was low. This may be due to the fact that the RPE-session component of the calculated PAI (session) did not precisely reflect the global exertion experienced during the entire maximal treadmill protocol among the 8-17 year old subjects. As such, evidence is lacking that supports the usefulness of RPE-session as a component of PAI (session) to predict energy expenditure of children and adolescents performing progressively incremented aerobic exercise.

5.4.3 Energy expenditure prediction using PAI (session) and selected physiological variables

To increase robustness of the model to predict energy expenditure during load incremented treadmill exercise a follow-on model was created that employed PAI (session), VO_2max ($L.min^{-1}$), VO_2max ($ml.kg^{-1}.min^{-1}$), and HRmax as potential predictor variables. The variables selected by the regression analysis for inclusion in the total Kcal prediction model were PAI (session), VO_2max ($L.min^{-1}$), and HRmax. This prediction model as shown below estimated total Kcal expenditure accrued during the entire load incremented treadmill exercise protocol:

Model VI :Total Kcal = -64.759+26.998(VO_2max)+0.305(HRmax)+0.001(PAIsession) $p<0.05$, SEE=10.46, $r = 0.918$, $r^2 = 0.842$.

The model demonstrated a strong positive and statistically significant correlation ($r = 0.918$) using responses derived during load incremented treadmill exercise. The PAI (session), VO_2max ($L.min^{-1}$), and HRmax explained 84.2% of the variance in total kcal expenditure of children and adolescents performing load incremented treadmill exercise. The correlation coefficient for the model was higher than observed by Weary et al. (178) for Kcal prediction models employing the PAI score alone. However, the strongest predictor($r = 0.88$, $r^2 = 0.78$) in Model VI was VO_2max ($L.min^{-1}$). The VO_2max is a measure of the maximal systemic aerobic energy production during exercise. As the exercise intensity progressed during the incremental protocol the rate of total body oxygen utilization also increased reaching maximal value at the point of treadmill test termination. Concurrently, Kcal expenditure to perform the locomotor activity also increased. Of the variables that entered Model VI, VO_2max ($L.min^{-1}$) was the strongest predictor of total Kcal expenditure. There is strong possibility that a higher VO_2max and HRmax enabled subjects to perform for longer duration during treadmill exercise. The longer treadmill performance was associated with higher total Kcal expenditure. Thus, the greater total Kcal expenditure reflected the relation between higher maximal aerobic power and longer treadmill performance time. As noted previously, in comparison to the PAI score calculated using momentary RPE (i.e. obtained directly during exercise), it seems that the PAI (session) calculated using RPE-session was less able to explain the total energy required to perform graded treadmill exercise. Here again, this outcome may reflect the lower sensitivity of RPE-session as a measure of global effort experienced over the total time course of the load incremented protocol for the pediatric sample that was studied.

5.5 EXPLORATORYANALYSISUSING ADJUSTED RPE TO ACCOUNT FOR THE "ZERO" CATEGORY BIAS

The "0" category on the OMNI Scale can present computation difficulties for exercise related indices such as the PAI. When computing the PAI, a "0"category rating on the OMNI Scale can result in a "0" PAI value. To address this computational problem, several alternative Adult OMNI Cycle scales have been developed and validated that employ numerical categories ranging from 1 to either 10 or 11(124).

The current perceptual data derived from the original Child OMNI Walk/Run Scale format evidenced a possible "0 problem" as noted in the Figures 3,4,5, and 6. That is, when examining individual data points there were a number of PAI scores calculated as zero, i.e. see Y axis of above listed figures. While not considered an aim of the present investigation, this observation suggests that additional calculations to account for "0" category bias could be performed for exploratory purposes only. In these follow-on exploratory calculations all the research questions were re-examined using an RPE adjustment to account for a potential "0" category bias in the present responses. Each individual RPE response was adjusted by adding one category unit to the original RPE i.e. 0 became 1; 1 became 2, etc. The PAI, PAI_{total}, and PAI (session) were recalculated using the adjusted momentary RPE-overall and RPE-session values. The following section presents statistical analyses employing the adjusted PAI, PAI_{total}, and PAI (session). A list of the r and r^2 values derived for Models developed using the original and adjusted RPE values is presented in Table 14.

Table 14. Comparison of prediction models developed using original and adjusted Child OMNI Walk/Run Scale.

Model No.		**Criterion variable**	**Original Scale**		**Adjusted Scale**	
Original Scale	**Adjusted Scale**		**r**	**r^2**	**r**	**r^2**
I	VII	Cumulative Kcal	0.74	0.54	0.75	0.56
II	VIII	Total Kcal	0.87	0.76	0.87	0.76
III	IX	Total Kcal	0.75	0.56	0.75	0.57
V	X	Total Kcal	0.36	0.13	0.38	0.14
VI	XI	Total Kcal	0.92	0.84	0.92	0.85

A positive ($p<0.05$) correlation between the adjusted PAI (PAI_{adj}) and VO_2 in $mL.kg^{-1}.min^{-1}$($r=0.75$) and VO_2in $L.min^{-1}$($r=0.619$) was observed. Heart rate also correlated significantly ($r=0.765,p<0.05$) with the PAI_{adj}. These regression calculations employed the adjusted RPE responses for the 49 subjects who had minute by minute step count data available.

Cumulative Kcal expenditure was estimated using the PAI_{adj} value according to the following prediction model:

Model VII :Cumulative Kcal = 18.805 + 0.006(PAI_{adj}) $p<0.05$, SEE=17.16, r=0.75, r^2=0.56.

The adjusted PAI_{total} ($PAI_{total(adj)}$) and selected physiological variables were used to develop a prediction model to estimate total Kcal expenditure. However, in this statistical iteration, the $PAI_{total(adj)}$ was not selected as a predictor variable:

Model VIII :Total Kcal = -71.56+0.361(HRmax)+28.858(VO_2max)$p<0.05$, SEE=12.48, r=0.87, r^2=0.76.

To make the adjusted prediction model more robust with greater practical application a follow-on regression analysis was undertaken that excluded VO_2max as one of the predictor variables:

Model IX :Total Kcal = -155.22+1.18(Height)+0.003($PAI_{total(adj)}$)$p<0.05$, SEE=16.81, r=0.75, r^2=0.57.

A prediction model was also calculated that first employed the adjusted PAI (session) alone. Then a model was calculated that employed the PAI_{adj} (session) along with selected physiological variables to predict total Kcal expenditure. The models were developed using all 84 subjects for whom total step count data were available.

Model X :Total Kcal = 36.05 + 0.004{PAI_{adj}(session)}, $p<0.05$, SEE=24.05, r=0.38, r^2=0.14

Model XI :Total Kcal = -64.759+26.998(VO_2max)+0.305(HRmax)+0.001 {$PAI_{adj(}$session)}$p<0.05$, SEE=10.36, r = 0.919 , r^2 = 0.845.

The correlation coefficients and strength of prediction of the various statistical models employing adjusted RPE data were reasonably similar to those determined for the models that employed the PAI derived from the “original” OMNI Scale format. Thus, the findings suggest that the Kcal prediction models employing PAI values based on RPE derived from the original OMNI Scale format and used presently to answer the primary research questions were acceptable for clinical/health fitness testing applications involving children.

5.6 PAI APPLICATION

Previous research has demonstrated that the PAI is an easy to use tool to predict Kcal expenditure during intermittent bouts of aerobic exercise among adults (178).The current study validates the PAI for use with a healthy, normally active pediatric population sample performing load incremented treadmill exercise. It is possible that such applications could be of significant value in weight management interventions for the pediatric population. This may be especially the case where prediction of aerobic energy expenditure during pre-participation exercise testing provides a baseline to prescribe a target exercise load (i.e. volume and intensity) for use in weight management programs.

Future investigations among children and adolescents may support the public health applications of the PAI as an easy to apply measure to estimate total physical activity load and it's associated Kcal expenditure in the pediatric population. Thus, the PAI may prove to be an effective component of exercise programming in normal weight children/adolescents and may also be of significant clinical value in obesity evaluation, prevention and treatment. Since, the PAI provides both objective and subjective monitoring of physical activity levels, it might act as motivation tool for maintaining a physically active lifestyle in children. The PAI can provide quantified goal setting, which can be tracked over the time course of an exercise program and can also provide in-task feedback to participants during individual training sessions. The measurable goals and immediate feedback regarding the attainment of these goals may reinforce participants to continue exercise participation.

The PAI is economical, easy to use, and provides objective and subjective monitoring of the exercise load and associated Kcal expenditure of aerobic exercise employing continuously incremented locomotor intensities. Once validated for other types of aerobic activities it is proposed that the PAI can facilitate development, implementation, and evaluation of exercise intervention programs intended to enhance health-related fitness.

5.7 CONCLUSION

Various studies worldwide and within the US have reported an increase in obesity prevalence in pediatric populations. This poses a significant health concern and emphasizes the need to follow ACSM physical activity recommendations. An effective exercise program consists of two key components, i.e. intensity (preferably relative) and volume. Therefore, when evaluating the effectiveness of an exercise program it is essential to consider these two components for a given performance mode. The PAI is a new measurement tool that incorporates both of these key dimensions of physical activity programming. The present investigation initially validated the PAI for children and adolescents performing a load incremented treadmill protocol. Next, prediction equations to estimate energy expenditure using the PAI, PAI_{total}, PAI (session), and selected behavioral and physiological variables were developed for children and adolescents performing load incremented maximal treadmill exercise.

The first step in the investigation was to establish the concurrent validity of the PAI for female and male children and adolescents performing a load incremented maximal treadmill protocol. Significant ($p<0.05$) positive correlations between the PAI and VO_2 ($mL.kg^{-1}.min^{-1}$) ($r=0.725$), and VO_2 ($L.min^{-1}$) ($r=0.607$), and HR ($beats.min^{-1}$) ($r=0.755$) were observed. These findings established a high level of concurrent validity for the PAI as a measure of total exercise load in a pediatric sample. Model I was developed to predict cumulative Kcal expenditure using PAI as a predictor variable:

Model I : Cumulative Kcal = 21.632 + 0.006(PAI) p<0.05, SEE=17.59, r=0.74, r^2=0.54.

The PAI_{total} and selected physiological and behavioral variables were used to develop prediction Model II to estimate total Kcal expenditure:

Model II :Total Kcal =-11.59+0.002(PAI_{total})+27.245(VO_2max) p<0.05, SEE=15.37, r=0.86, r^2=0.739.

The PAI (session) alone and in combination with selected physiological variables was used to develop prediction Models V and VI to estimate total Kcal expenditure:

Model V : TotalKcal = 38.6 + 0.004(PAIsession), p<0.05, SEE=24.23, r=0.36, r^2=0.13.

Model VI :Total Kcal = -64.759+26.998(VO_2max)+0.305(HRmax)+0.001 (PAIsession) p<0.05, SEE=10.46, r = 0.918 , r^2 = 0.842.

In comparison to the PAI (session), PAI was a stronger predictor of Kcal expenditure during a load incremented treadmill protocol in a sample of 8 to 17 year old children and adolescents.

Further studies are required to develop a more extensive understanding of the PAI and PAI (session) in exercise and physical activity programming for pediatric populations. Also, the generalizability of findings of this study is limited to healthy children and adolescents performing load incremented maximal treadmill exercise. The PAI has public health implications, provides an easy tool to estimate total physical activity load (i.e. volume x intensity) and predicts Kcal expenditure in children and adolescents performing a standard treadmill protocol. It is postulated that the PAI can be an effective component of exercise programming in obesity prevention and treatment. The PAI can also act as a motivation tool for maintaining a physically active lifestyle in children as it provides both objective and subjective monitoring of physical activity levels.

5.8 RECOMMENDATIONS

Based on the findings of this investigation, future research regarding the PAI should focus on following:

- In the present investigation, the PAI was used to predict energy expenditure during a load incremented treadmill exercise protocol performed by children and adolescents. It would be useful to develop energy expenditure prediction models based on the PAI for differing exercise testing protocols, aerobic activity modes, and exercise intensities. In this regard the PAI and associated energy prediction models should be validated for steady state continuous aerobic exercise of both low and high intensity, intermittent/interval exercise formats of the type typically employed in health-fitness and athletic conditioning programs and free-form play and recreational activities. In addition, validation of the PAI for exercise testing protocols should control response demand-bias that can be evident in a progressively incremented protocol such as employed in the current study.

- The current investigation developed and validated PAI based Kcal prediction models for treadmill exercise. It would be interesting to examine the validity of PAI estimated Kcal expenditure across various aerobic exercise machines i.e. elliptical, cycle ergometer, stair climber, arm ergometer etc.
- The present investigation produced generalized prediction equations for a cohort of both female and male children and adolescents who were: (a) Caucasian and African-American, (b) non-obese and obese, and (c) ranged in age from 8 to 17 years. It is recognized that generalizability of these PAI based prediction models is restricted to pediatric subjects having these characteristics. Future studies should develop energy expenditure prediction models that employ the PAI for a wide range of pediatric population subsets, i.e. different ethnicities, BMI percentile classifications, maturation levels, leg lengths, and clinical status.
- Previous studies have shown a negative correlation between BMI and pedometer step counts tabulated over a defined time period for children and adults. Future investigations should study the impact of BMI on PAI validity. In addition, further research should explore the potential influence of BMI in explaining variance in energy expenditure prediction models that employ PAI values.
- Only one type of commercially available pedometer was used to measure step counts during the load incremented treadmill protocol. This methodological choice may have limited generalizability of the prediction models derived presently and requires follow-on research. Future investigations should examine PAI calculations that employ movement data derived from a range of

pedometer/accelerometer models and that employ a number of different anatomical placements of these instruments.

- Inter-individual differences in gait cycle and stride length may have affected the step count measurement used to calculate individual PAI scores. To account for variations in stride length, future research to establish the validity of the PAI to predict Kcal expenditure of various locomotor intensities should use pediatric subjects that vary in stature and lower limb length.
- Future research should further investigate the role of other variables along with the PAI in developing Kcal prediction models i.e. aerobic fitness level, training status, heart rate, and specific types of leisure time physical activity, and sedentary behaviors.
- Future research should employ an alternative version of the OMNI Scale where the "0" category is eliminated or specifically designated as a "resting only response". This eliminates a potential "0" category perceptual bias in calculating the PAI.
- Use addition (PAI = volume + intensity) rather than multiplication in calculating the PAI to eliminate the "zero" category bias when employing the original OMNI Scale format.
- Further research regarding the development and validation of a statistical model that uses PAI (session) to predict Kcal expenditure among children and adolescents appears warranted. Such research will need to examine the validity of RPE-session measurements in the pediatric population. A study to further validate RPE-session measurements should emphasize "global" perceptual scaling and

anchoring procedures, scaling practice, and possible use of segmented RPE-session responses.

- Validate energy expenditure prediction models using PAI values derived during a field performance test such as the Progressive Aerobic Cardiovascular Endurance Run (PACER) test.

APPENDIX A

Figure 8. Caloric equivalent of O_2 for each RER value

RER	kcal·L^{-1} O_2	% Carbohydrate	% Fat	RER	kcal·L^{-1} O_2	% Carbohydrate	% Fat
0.70	4.686	0.0	100.0	0.86	4.875	54.1	45.9
0.71	4.690	1.1	98.9	0.87	4.887	57.5	42.5
0.72	4.702	4.8	95.2	0.88	4.899	60.8	39.2
0.73	4.714	8.4	91.6	0.89	4.911	64.2	35.8
0.74	4.727	12.0	88.0	0.90	4.924	67.5	32.5
0.75	4.739	15.6	84.4	0.91	4.936	70.8	29.2
0.76	4.751	19.2	80.8	0.92	4.948	74.1	25.9
0.77	4.764	22.3	77.2	0.93	4.961	77.4	22.6
0.78	4.776	26.3	73.7	0.94	4.973	80.7	19.3
0.79	4.788	29.9	70.1	0.95	4.985	84.0	16.0
0.80	4.801	33.4	66.6	0.96	4.998	87.2	12.8
0.81	4.813	36.9	63.1	0.97	5.010	90.4	9.6
0.82	4.825	40.3	59.7	0.98	5.022	93.6	6.4
0.83	4.838	43.8	56.2	0.99	5.035	96.8	3.2
0.84	4.850	47.2	52.8	1.00	5.047	100.0	0.0
0.85	4.862	50.7	49.3				

Data derived from Lusk G. *Science of nutrition*. 4th ed. Philadelphia: WB Saunders, 1928.

APPENDIX B

Figure 9. IRB approval for research study

University of Pittsburgh
Institutional Review Board

3500 Fifth Avenue
Pittsburgh, PA 15213
(412) 383-1480
(412) 383-1508 (fax)
http://www.irb.pitt.edu

Memorandum

To: Silva Arslanian, MD
From: Sue Beers, PhD, Vice Chair
Date: 6/7/2011
IRB#: REN11040033 / IRB0405074
Subject: Childhood Metabolic Markers of Adult Morbidity in Blacks

The Renewal for the above referenced research study was reviewed and approved by the Institutional Review Board, Committee D, which met on 6/2/2011.

Please note the following information:

The risk level designation is Greater Than Minimal Risk.

Approval Date: 6/2/2011
Expiration Date: 6/1/2012

Please note that it is the investigator's responsibility to report to the IRB any unanticipated problems involving risks to subjects or others [see 45 CFR 46.103(b)(5) and 21 CFR 56.108(b)]. The IRB Reference Manual (Chapter 3, Section 3.3) describes the reporting requirements for unanticipated problems which include, but are not limited to, adverse events. If you have any questions about this process, please contact the Adverse Events Coordinator at 412-383-1480.

The protocol and consent forms, along with a brief progress report must be resubmitted at least **one month** prior to the renewal date noted above as required by FWA00006790 (University of Pittsburgh), FWA00006735 (University of Pittsburgh Medical Center), FWA00000600 (Children's Hospital of Pittsburgh), FWA00003567 (Magee-Womens Health Corporation), FWA00003338 (University of Pittsburgh Medical Center Cancer Institute).

Please be advised that your research study may be audited periodically by the University of Pittsburgh Research Conduct and Compliance Office.

APPENDIX C

Figure 10. Physical activity and exercise questionnaire

1. How many of the past 14 days have you done at least 20 minutes of exercise **hard** enough to make you breath heavily and make your heart beat fast? (Hard exercise includes, for example, playing basketball, jogging, fast dancing or bicycling; include time in physical education class)

    1. None
    2. 1 to 2 days
    3. 3 to 5 days
    4. 6 to 8 days
    5. 9 or more days

2. How many of the past 14 days have you done at least 20 minutes of **light** exercise that **was not** hard enough to make you breath heavily and make your heart beat fast? (Light exercise includes, for example, playing baseball, walking or slow bicycling; include time in physical education class)

    1. None
    2. 1 to 2 days
    3. 3 to 5 days
    4. 6 to 8 days
    5. 9 or more days

3. During a normal week, how many hours **a day** do you watch television and videos, or play computer or video games before and after school?

    1. None
    2. 1 hour or less
    3. 2 to 3 hours
    4. 4 to 5 hours
    5. 6 or more hours

4. During the past 12 months, how many team or individual sports or activities did you participate in on a **competitive** level, such as varsity or junior varsity sports, intramurals, YMCA or other out-of-school programs.

    1. None
    2. 1 activity
    3. 2 activities
    4. 3 activities
    5. 4 or more activities

What activities did you compete in? 1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________
7. ______________

APPENDIX D

Figure 11. Past year leisure-time physical activity

I will read list of activities, if you have participated in any of these activities at least 10 times in the past year, do let me know. I will also ask you the months, days.wk^{-1}, and days.min^{-1} you participated in each activity. If you participated in an activity that is not listed, include that in this list too. Do not include time spent in school physical education classes. Make sure you include all sport teams that you participated in during the last year.

____ Aerobics
____ Band/Drill Team
____ Baseball
____ Basketball
____ Bicycling
____ Bowling
____ Cheerleading
____ Dance Class
____ Football
____ Garden/Yard Work
____ Gymnastics
____ Hiking
____ Ice Skating
____ Roller Skating
____ Running for Exercise
____ Skateboarding
____ Snow Skiing
____ Soccer
____ Softball
____ Street Hockey
____ Swimming (Laps)
____ Tennis
____ Volleyball
____ Water Skiing
____ Weight Training
____ Wrestling (Competitive)
Others
____
____
____

List each activity that you checked above in the "Activity" box below, check the months you did each activity and then estimate the amount of time spent in each activity.

Activity	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Months Per Year	Days Per Week	Minutes Per Day

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