Risk Classification Using Physical Activity

and Body Composition of Children in Grades 3, 4 and 5

BY

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"Risk Classification Using Physical Activity and Body Composition of Children in Grades 3, 4, and 5"

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

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ABSTRACT

Children in grades 3 - 5 were assessed for BMI, body fat (BF) and physical activity (PA, triaxial accelerometry). Adherence to current published Canadian Physical Activity Guidelines for children (Health Canada / Canadian Society for Exercise Physiology) was assessed using a unique automated activity analysis template. A classification system is proposed based upon body composition and physical activity; characterizing risk for chronic disease / sub-optimal development this sample (n = 419).

Application of this novel risk classification system identified 84.9% (energy expenditure) to 97.2% (active time) of children within various levels of risk for chronic disease due to combinations of insufficient physical activity / undesirable body composition.

This study demonstrates a novel method of in depth accelerometry analysis in children and proposes a risk classification system useful for risk assessment, intervention development and outcome measurement in relation to prevention of chronic disease and promotion of optimal development in children.

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Abbreviations

AA – all activity > 51 cal/kg/min, regardless of continuity

AC - all continuous activity > 51 cal/kg/min, identified within continuous bouts

ACSM – American College of Sports Medicine

ACT - active enough for health benefits (≥ 8 kcal/kg/d)

AM - all moderate activity > 96 cal/kg/min, regardless of continuity

AT – active time at moderate or vigorous intensity physical activity

BF – body fat

BMI – body mass index (kg/m^2)

BMR – basal metabolic rate

CB – continuous bouts (of physical activity)

CFLRI – Canadian Fitness and Lifestyle Research Institute

CFS – Canadian Fitness Survey

CSEP – Canadian Society for Exercise Physiology

DEXA - dual energy x-ray absorptiometry

EE – energy expenditure

FFM – fat free mass (kg)

FM – fat mass (kg)

HC – Health Canada

IA – (physically) inactive (<3 kcal/kg/d)

LA – low active (6 – 7.99) kcal/kg/day

MET – metabolic equivalent

NHANES - National Health and Nutrition Examination Surveys

NLSCY - National Longitudinal Survey of Children and Youth

NPHS - National Population Health Survey

OB – obese

OW – overweight

PAM – Physical Activity Monitor

PARK – Physically inactive: At Risk Kids

PI – physical inactivity

VLA – very low active (3 – 5.99 kcal/kg/d)

Introduction

A dramatic increase in the rates of overweight (OW) and obesity (OB) in children has occurred over the last two decades (Tremblay, Katzmarzyk et al. 2002). Since physical activity and body composition are highly correlated measures in children (Rowlands, Eston et al. 1999; Trost, Kerr et al. 2001), one can propose that the increasing rates of OW and OB are manifested by physical inactivity resulting in a net positive caloric balance. Physical inactivity, OW and OB in childhood are associated with risk for disease and presence of disease in both childhood and adulthood (Geiss, Parhofer et al. 2001; Brage, Wedderkopp et al. 2004; Brage, Wedderkopp et al. 2004; Katzmarzyk and Janssen 2004). Thus, increased physical activity and optimization of body composition in children can represent reduced risk or prevention of disease.

In relation to disease prevention, it is accepted that primary prevention refers to intervention applied before any biological disease related changes have occurred within an individual. Intervention directed toward OW or OB individuals would not be considered primary prevention, as studies have confirmed the presence of disease related biological changes in these individuals. Primary prevention must be directed to those children who are not achieving sufficient physical activity for health benefit but are not yet OW or OB. We operationally define this group of children by using the term "PARK" – **P**hysically inactive **A**t **R**isk **K**ids. While these children are at risk for the negative effects associated with physical inactivity and lack the benefits from PA, they would not be classified as at risk based solely upon their body composition measures. Obesity is not the only measure related to risk of disease, as physical inactivity is a risk factor for development of disease and related to sub-optimal physical ability and development. As such, risk classification systems for sub-optimal growth and development, and disease should use both of these lifestyle factors; body composition and physical activity.

A risk classification system based upon both objective measures of PA and direct / multiple measures of body composition is necessary to stratify risk for disease and identify various "at risk" groups. Physical activity guidelines for maintaining or improving health status have been produced for children (www.hc-sc.gc.ca). Thresholds for OW, obesity, and body fat (BF) have been developed for children and related to risk for disease (Schaefer, Georgi et al. 1998; Katzmarzyk, Tremblay et al. 2003). These published PA and BC guidelines and thresholds can provide a basis for a hierarchical system to classify risk for disease and sub-optimal development for children.

Self reported PA participation and indirect BC measures (i.e. BMI) have been shown to be unreliable assessment tools in children. Recently, there are several studies (Brage, Wedderkopp et al. 2004; Brage, Wedderkopp et al. 2004) which have sought to define specific risk factors for disease in relation to objective measures of PA and direct measures of BC in children. These studies have been successful in linking PA, BC and specific disease parameters. However, there has not been an identified study to date that has produced a stratified risk classification scheme combining objective measures of PA and multiple measures of BC. To truly assess risk for disease, direct preventative intervention, and assess outcomes of interventions, risk classification must occur to elucidate specific groups toward which primary, secondary and tertiary prevention can occur.

Thus the purpose of this study is twofold. There are no identified studies to date which have assessed compliance of a large sample of Manitoban children to the PA recommendations through the use of objective PA measures. This study will assess adherence to PA guidelines in a large sample of children with objective activity measures, as well as compare BMI and body fat as body composition classification tools for children. The main purpose of this study will be to use published guidelines and thresholds for PA and BC to develop a risk classification tool for children. "Risk" will refer to risk for inactivity related disease as well as risk for sub-optimal development. This classification scheme will be applied to a large dataset of third to fifth grade Manitoban children. Objective PA measures and direct / multiple BC measures will be used to stratify risk for disease within this sample, identifying specific groups toward which disease prevention and health promotion can be targeted.

Review of Literature

Overweight and obesity in children – current statistics

Over 30% of Canadian children are OW, and up to 10% are OB (Tremblay, Katzmarzyk et al. 2002). Tremblay and colleagues derived these statistics using height and weight data from the National Longitudinal Survey of Children and Youth (NLSCY) and the National Population Health Survey (NPHS) (1996). Body Mass Index (BMI) values for the children were calculated and compared with international age specific BMI values to classify children as OW or OB (Cole, Bellizzi et al. 2000). BMI was used as a health measure of children, and represented a tripling of the rates of OW, and a quintupling of the rates of obesity when compared to BMI data from the 1981 Canada Fitness Survey (CFS). In 1981, 11% of boys and 13% of girls were classified as OW, while 2% of boys and girls were classified as OB. In 1996, 33% of males and 27% of females were classified as OW, and 10% and 9% of males and females respectively were classified as OB. The rapid and substantial rate of increase of childhood obesity in Canada of three to fivefold over the last decade far exceeds the adult rate. Over this same time period, the adult rate of OW increased from 48 to 57% in men and from 30 to 35% in women. The prevalence of obesity rose from 9 to 14% and 8 to 12% in men and women respectively (Tremblay, Katzmarzyk et al. 2002). Lifestyle factors (over-eating and lack of physical activity) have been identified as the main contributors to the current OW and OB levels (Bianchini, Kaaks et al. 2002).

Relating body composition to physical activity and physical fitness

Research has demonstrated that OW individuals are generally less physically active, and less physically fit than those who are not OW (Gortmaker, Must et al. 1996; Rowlands, Eston et al. 1999; Trost, Kerr et al. 2001; Janz, Levy et al. 2002; Lazzer, Boirie et al. 2003; Tremblay and Willms 2003; Abbott and Davies 2004; Brage, Wedderkopp et al. 2004). Rowlands and coworkers (Rowlands, Eston et al. 1999) collected data on 34 children ages 8-10 years; BMI and skin folds (sum of seven skin folds) were used for anthropometric measures. Physical activity was measured by accelerometry (Tritrac R3D, 1 min), pedometry and heart rate (HR). Aerobic fitness was assessed by a maximal treadmill test (Bruce protocol). A significant positive relationship was found between activity level and fitness ($r = 0.66$, $P < 0.01$), and a significant negative relationship was found between activity level and body fatness ($r = -0.42$, $p < 0.05$). Comparison between the ability of BF versus BMI to predict fitness or activity level was not reported in this study.

Trost et al (Trost, Kerr et al. 2001) used accelerometry (CSA 7164) to compare activity of OB (n=54) and non OB (n=130) children (mean age 11.4 years). They concluded that OB (vs. non OB) children not only spend significantly less time per day physically active, but also less time in moderate (62.6 min/d vs. 78.2 min/d) and vigorous (7.1 min/d vs. 13.5 min/d) levels of activity. Assessment of continuous activity during which intensity was maintained equal to or greater than 3 METS demonstrated that OB children are involved in significantly fewer 5, 10 and 20-minute CB of activity in a day.

In a sample of 47 children (5 – 10.5 years, mean 8.4), Abbott et al (Abbott and Davies 2004) also found a significant inverse relationship between physical activity level (doubly labeled water technique DLWT and Tritrac R3D accelerometry) and BF (mass minus fat free mass as determined by DLWT) and BMI ($r = -0.43$, $p = 0.002$ and $r = -.45$, $p = 0.001$). The relationship between BF and minutes spent participating in vigorous intensity activity (defined by the authors as >1999 accelerometer counts/minute) demonstrated a significant negative correlation ($r = -0.39$, $p = 0.014$). Interestingly, while BMI mirrored this trend, statistical significance was not achieved. The difference in results based on the two measure of body composition (BMI and BF) illustrates the importance of using more direct body composition measures than simply BMI; in that BMI has inherent limitations as a measure of body composition resulting in greater variability.

Although the cross sectional nature of these studies prevent comment on causality, the use of objective physical activity measures and percent body fat within these studies has established that OW and OB children on average have lower physical fitness and lower physical activity levels. The lack of a perfect correlation between PA and BC demonstrates the need to consider both of these parameters when classifying risk for disease in children.

Media Use by Children

Reduction in physical activity participation and increasing rates of OW and obesity have been attributed in part to increased rates of media use (i.e. television viewing) (Gortmaker, Must et al. 1996; Epstein and Roemmich 2001; Janz 2002; Tremblay, Katzmarzyk et al. 2002). Janz et al. (Janz, Levy et al. 2002), using data on 467 (217 males, 250 females) children ages 4 – 6 from the Iowa Bone Development study examined the relationship between accelerometry measured physical activity, parental report of television viewing and body composition as assessed by dual x-ray absorptiometry (DEXA). An inverse correlation was demonstrated between time spent in vigorous physical activity (≥ 6 METS) and BF, and a significant positive correlation between time spent viewing T.V. and BF. Males in the lowest quartile of vigorous physical activity were 4.5% fatter than those in the highest quartile. The same comparison performed on females revealed a 3.7% difference. Boys and girls who watched the highest amounts of T.V. had an average of 3.7% more body fat than those who watched the least amount of T.V.

A study performed in the U.S. (n = 746, ages 10 – 15 years) identified children who watch greater than 5 hours of television per day as having up to 4.6 times increased chance of being OW than those who watch two hours or less per day (Gortmaker, Must et al. 1996). Similarly, Tremblay et al (Tremblay and Willms 2003) proposed a risk classification system relative to T.V. viewing and OW using data from Canadian children (n = 7216, ages 7 – 11). Greater than 2 hours of T.V. viewing per day represented a risk for OW within this sample, while > 3 hours of viewing per day represented risk for OB.

As time spent watching television, playing video games or using other media (internet, etc.) is time spent physically inactive, this is in essence reflection of a leftward shift in the physical activity distribution toward lower intensities of activity or increased time in sedentary behavior, contributing to the increasing rates of OW and OB in children. These results further confirm the association between physical activity participation and body composition.

Tracking of overweight and obesity

Overweight children tend to remain overweight into adulthood, thus prevention of OW is key. Whitaker et al (Whitaker, Wright et al. 1997) established that the degree of obesity (BMI) at a younger age was a factor in predicting obesity (BMI) in adolescence and adulthood. Obese and very OB categories were classified based on the 85th and 95th centiles respectively, as identified from the National Health and Nutrition Examination Surveys (NHANES). Results from this study demonstrated that a 'very OB' child at any age had a greater risk of obesity in adulthood than both an 'OB' child and a child of 'non OB' status. For example the category of 'very OB' 10-14 year olds had an odds ratio of 44.3 (range 16.3 -120) of future obesity, while the category of 'OB or very OB' children of the same age had an odds ratio of 28.3 (15 - 53.5). This tendency for OW and OB to persist provides another reason to strive for prevention of OW and OB in childhood.

Parental OW and OB also plays a substantial role in the tracking of childhood BMI. Whitaker and colleagues have found that an OW child with parents having non OW BMI (< 25 kg/m^2) had a 60-78% chance of OW at age 20, while an OW child with one or both parents OW (> 25 kg/m^2) had a 78-100% chance of OW at age 20. Tracking tendencies increased with increasing BMI of parents.

Body composition, physical activity and risk for chronic disease in adulthood

Arguably the most important reason to monitor body composition and strive to increase physical activity levels and prevent OW is the association between inactivity and OW and disease. Physical inactivity and OW have not only been associated with disease in adulthood; risk for disease is also dramatically increased in inactive, OW children.

Numerous studies have directly linked inactivity and OW to major disease states in adulthood such as cancer, diabetes, osteoporosis, cardiovascular and respiratory disease (Sothern, Loftin et al. 1999; Geiss, Parhofer et al. 2001; Ball and McCargar 2003; Reilly, Methven et al. 2003). A recent review (Katzmarzyk and Janssen 2004) estimated that in 2001 the economic burden of physical inactivity (medical expenditure, work output loss, morbidity and mortality) was $5.3 billion, and that due to obesity was $4.3 billion. One can only expect the cost of adulthood physical inactivity and OW to increase at a rate reflective of the recent increases in childhood OW and obesity, as these children move into adulthood.

Dietz (Dietz 1998) compiled data from the Third Harvard Growth Study, which spanned from 1922 to 1988, to examine the relationship between BC in youth and disease in adulthood. Subjects who were OW as adolescents had higher rates of diabetes, coronary heart disease, hip fractures and gout in adulthood. This adult subgroup was also found to achieve lower socioeconomic status and had lower rates of marriage. Recently, much attention has been directed to a clustering of disease risk factors (hyperinsulinemia, low glucose tolerance, hyperlipidemia, hypertension and obesity) termed “the metabolic syndrome” representing high risk for cardiovascular disease and diabetes (Brage, Wedderkopp et al. 2004; Weiss, Dziura et al. 2004). It is important to note that “metabolic syndrome” does not include all physical activity related conditions such as fatal cancers and osteoporosis, etc. However, increased “metabolic risk” is demonstrated in both adults and children with low physical activity and low physical fitness levels (Brage, Wedderkopp et al. 2004; Franks, Ekelund et al. 2004).

The International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) produced a statement regarding the preventative nature of physical activity and weight control for cancer (IARC Handbooks of Cancer Prevention, Volume 6;5). Bianchi and colleagues (Bianchini, Kaaks et al. 2002) summarized this statement, reporting that sufficient literature is available to identify a causal relationship between OW and cancer of the colon, breast, esophagus and kidney. Limited evidence provides probable links between physical inactivity and cancer of the endometrium and prostate.

Body composition, physical activity and risk for chronic disease in childhood

Inactivity, OW and OB represent risk for disease in childhood as well as adulthood. Studies are revealing that many lifestyle related diseases and risk factors previously thought only to manifest in adulthood are now presenting in children, such as type 2 diabetes and predictors for cancer and cardiovascular disease (Silverstein and Rosenbloom 2001; Vainio, Kaaks et al. 2002; Woo, Chook et al. 2004).

A review of literature performed by Reilly and colleagues (Reilly, Methven et al. 2003) outlined the long term and short term consequences of childhood obesity. Long-term consequences were identified as social and economic effects (income, education level achieved), persistence of obesity into adulthood and increased mortality (including increased cardiovascular morbidity and mortality). Short-term consequences included psychological impact (low self esteem, behavioral problems), presence of cardiovascular risk factors, and a moderate link to other health problems (asthma, type 1 diabetes, low grade systemic inflammation, and orthopedic abnormalities).

A study by Geiss et al (Geiss, Parhofer et al. 2001) investigated OW parameters to determine their predictive ability in relation to the presence of adverse cardiovascular changes in children ages 4-9. Using either BMI or Ponderal index (kg/m^3) to classify children, OW children were found to differ significantly from acceptable weight children in terms of cardiovascular risk profiles. Overweight children had higher systolic and diastolic blood pressure, higher levels of apolipoprotein B, fibrinogen and LDL cholesterol and lower HDL cholesterol. Freedman et al (Freedman, Dietz et al. 1999) found similar results using BMI as a measure of OW in a sample of children ages 5-17. Children with BMI greater than the 85^{th} centile were found to have a substantial increase in the presence of cardiovascular risk factors. Overweight children were shown to be 9.7 times as likely as non OW children to have 2 CV risk factors, and 43.5 times as likely to have 3 or more risk factors. An increased prevalence of risk factors was found with further increases in BMI. Within their sample, 61% of children (mean age 11.9 years) who were OW had at least one cardiovascular risk factor present.

Recently, a study comparing disease risk in OB and non-OB children (n = 40, ages 6 – 9 years) found the increased presence of a cancer-linked hormone in the OB group when compared to the non-OB group (Gascon, Valle et al. 2004). Accordingly, recommendations from the IARC focus on the prevention of OW and obesity in children for the prevention of cancer.

Similarly, the recent increase in type 2 diabetes in children has been attributed to the increased rates of OW/OB and physical inactivity (Ehtisham and Barrett 2004). A significant inverse relationship has been found between accelerometry assessed PA and fasting insulin ($p < 0.001$) In this same study, a significant positive relationship was found between insulin and body weight ($p < 0.001$) and skin fold thickness ($p < 0.001$) (Brage, Wedderkopp et al. 2004). Importantly, the relationship between insulin and physical inactivity remained significant when BMI and skin folds were adjusted for within the sample, indicating this relationship was independent of BC measures. These researchers have also assessed PA and fitness in relation to the "metabolic syndrome" (Brage, Wedderkopp et al. 2004). Risk factors associated with the metabolic syndrome were measured and converted to a standardized "metabolic syndrome score". A significant inverse relationship was present in this sample ($n = 589$, mean age 9.6 years) between metabolic syndrome score and PA, and a significant interaction was present between PA and physical fitness (maximal cycle ergometer test). Independently, physical fitness demonstrated a significant inverse relationship ($p = 0.033$) to insulin, triglycerides, systolic BP and skin fold thickness.

Benefits of Physical Activity

The benefits of physical activity reach further than disease prevention. Physical activity provides multiple health benefits in addition to the absence of disease. Specifically in children physical activity increases muscle and bone mass with the potential to decrease osteoporosis (Janz 2002). Physical activity improves cardiovascular fitness (Rowlands, Eston et al. 1999) and psychological profile (including self esteem) (Boreham and Riddoch 2001). Studies report that moderate and above moderate intensity activity is necessary to induce positive health related changes in skeletal mass, muscle mass and cardiovascular parameters, and provide protection against disease (Uusi-Rasi, Haapasalo et al. 1997; Sothern, Loftin et al. 1999). The benefits of physical activity and risks associated with inactivity necessitate the inclusion of an objective PA measure (in addition to BC) into a risk classification system. This inclusion is necessary to properly describe risk and essential to identify those individuals who are inactive but not yet OW (PARK).

Physical Activity Recommendations for Children

Acknowledging the benefits of physical activity in childhood, Health Canada (HC) and the Canadian Society for Exercise Physiologists (CSEP) together developed specific recommendations for physical activity in children, youth and adolescence. Relative to a child's body mass, HC and CSEP recommend daily energy expenditure from PA of at minimum 8 kilocalories per kilogram of body mass per day (kcal/kg/day) to provide health benefit. The Physical Activity Guidelines for Youth (www.hc-sc.gc.ca) recommend accumulation of 90 minutes of physical activity per day (60 minutes of moderate intensity activity and 30 minutes of vigorous intensity activity) on most days of the week to accrue health benefits. Physical activity guidelines for children (HC and CSEP) further propose that activity should be accumulated in 5-10 minute bouts, therefore placing an emphasis not only on intensity but also on duration of activity. These recommendations were made despite the lack of characterization of activity bouts of children in terms of duration and intensity.

Physical activity guidelines were developed in the context of the benefits for a child's current and future health status. Therefore, those that do not achieve the target levels specified in these recommendations should be considered at risk for disease or suboptimal physical and psychological development due to inadequate physical activity.

Risk Classification: The use of physical activity guidelines, objective measures of activity and body composition

As previously stated, no identified study to date has combined objective measures of PA and direct measures of BC to stratify risk for disease in a large sample of Canadian children. In addition, there has not been a study identified which uses objective measures to assess adherence to HC/CSEP PA guidelines for children. Current assessments have been made using self reported activity; however self report has been repeatedly shown to provide inaccurate measures of activity in children and adults.

Objective measures are necessary to obtain the most valid assessment of activity (Rowlands, Ingledew et al. 2000; Trost, Pate et al. 2002) as self reported activity analysis in children and adults results in over-estimation of activity participation (Buchowski, Townsend et al. 1999). A review of self report techniques (Sallis and Saelens 2000) found a high range and generally low validity (0.07 – 0.88) for PA questionnaires in children, and other studies show only low to moderate correlation between self report and objectively measured activity (-0.03 – 0.51), with the tendency to over-report activity, up to 100% (Janz, Witt et al. 1995; Epstein, Paluch et al. 1996).

The most accurate measures of energy expenditure in an individual would be through direct calorimetry (the measure of heat production) or indirect calorimetry (measure of oxygen consumption) to estimate metabolic rate and thus derive energy expenditure associated with a particular activity. For assessment of free living activities (i.e. play in children), a less cumbersome method of measurement would have the least impact on regular activity levels and patterns. Heart rate monitoring, pedometry and accelerometry are among tools that are used to estimate energy expenditure from activity. A study assessing the validity of these tools against oxygen uptake demonstrated triaxial accelerometry to be the best measure of energy expenditure of children's activity when compared with scaled oxygen uptake (sVO2) (Eston, Rowlands et al. 1998). Children's activities assessed in the validation study included walking and running on a treadmill, hopscotch, playing catch and coloring. A correlation of 0.83 was demonstrated between triaxial accelerometry (Tritrac) and oxygen uptake. The RT3 accelerometer (used within the present study) was developed to replace the Tritrac (due to its bulky nature) and uses the technology of the Tritrac. The RT3 and has since demonstrated a significant correlation (0.87) with sVO2 in the measurement of various physical activities (walking / running on a treadmill, kicking a ball, hopscotch and quiet sitting) (Rowlands, Thomas et al. 2004), thus can be considered an acceptable tool to monitor activity in children.

Objective measures of activity are also important when relating activity to body composition, as the size of the observed relationship between these measures are significantly related ($p < 0.001$) to the activity measure used (Rowlands, Ingledew et al. 2000). In a review by Rowlands and colleagues, no relationship was demonstrated between HR and body composition ($r = 0.00$). The lowest relationship between body composition and physical activity was observed with the use of questionnaires ($r = -0.14$), and the highest with the use of motion counters ($r = -0.18$) and observation ($r = -0.39$).

Similar to the varying strength of relationship between activity and body composition depending on the activity measure used, the reported prevalence of OW and obesity depends on the method (BMI, skin folds, DEXA, Bioimpedance, etc) and the thresholds used to define OW and obesity (Ball and McCargar 2003). While studies have shown relationships between presence of disease risk factors and BMI (Geiss, Parhofer et al. 2001; Katzmarzyk, Tremblay et al. 2003) with increased risk detected at increased BMI levels, it is recommended (when practical) to use more than one measure to assess body composition. BMI is understood to be an indirect measure of body composition

(Wang 2004) and superior for population analysis (due to simplicity and low level of training required to assess) versus measures suitable for assessment of the status of an individual (such as skin folds, hydrostatic weighing, and DEXA) (Pietrobelli, Faith et al. 1998; Widhalm and Schonegger 1999; Widhalm, Schonegger et al. 2001). Therefore, a tool to classify risk for inactivity and OW related disease should be based upon both objective measures of activity and multiple or direct measures of body composition.

Relevance

Studies have found significant increased risk of disease with decreasing levels of PA and increasing BMI and BF values (Katzmarzyk, Tremblay et al. 2003; Brage, Wedderkopp et al. 2004; Brage, Wedderkopp et al. 2004; Woo, Chook et al. 2004). The next logical step is to develop an easily applicable tool to classify various levels of disease risk in children based upon these measures using published PA and BC thresholds.

This study will be the first to assess compliance of a large sample of Manitoban children to the current HC/CSEP PA guidelines through the use of objective PA measures. As this study also has direct BC measures for these children (skin folds), the relationship between PA and BC will be assessed in this sample and related to the literature.

Finally, this study will propose a tool based upon published guidelines for PA and BC to classify risk for inactivity and OW related disease and sub-optimal development in children. The classification tool will be applied to this sample of grades 3 – 5 children to stratify risk for disease / inadequate physical development based upon their individual PA and BC measures. Elucidation of specific risk groups through the use of a non invasive, easily applicable tool will not only describe risk, but can also facilitate intervention development through the targeting of individual groups, and allow objective outcome assessment of physical activity interventions in children. The use of a classification scheme with four levels of risk (very low, low, moderate and high) and 16 individual classes (four BC classes * four PA classes) provides a level of detail especially useful for intervention outcome assessment. Not only can an investigator visualize efficacy of an intervention (general increases in PA or optimization of BC within the entire group); the unique interplay between these measures can be examined to determine if the intervention was effective in changing only one measure (PA vs. BC), both measures (PA and BC) or was superior for effecting change within certain risk classes but not others. By monitoring the initial and final risk class of individuals (pre and post intervention) one would be able to determine within which group the intervention was effective for changing PA, BC or both.

The link between inactivity, OW and disease has been established in the literature. There is dire need for interventions to increase activity and optimize body composition to prevent and reduce chronic disease and optimize development. Detailed, objective outcome assessment applied to interventions are crucial to determine efficacy and further direct refinement of interventions to continuously progress toward increased physical activity levels and optimization of health and development of children.

Purpose

The purpose of this study was to develop a classification system based upon objective measures of intensity and duration of physical activity (accelerometry) and body composition (skin folds and BMI), to classify children into categories of risk for the development chronic disease and inadequate physical development. A secondary purpose was to examine compliance of Manitoban children to the current PA guidelines.

Objectives

Objective 1:

The first objective is to develop and validate an automated analysis template for accelerometer data and then to apply this template to classify PA in terms of intensity and duration in relation to HC/CSEP guidelines. Thresholds will be used for intensity and duration of physical activity to allow classification of children into the categories (based on PA) of: inactive, very low active, low active and active enough for health benefits. An "active time" classification will also be applied relating time spent in moderate and vigorous intensity activity to HC/CSEP guidelines. The physical activity classification of children using objective data will be compared with current Canadian statistics from self report.

Objective 2:

A second objective is to classify children according to body composition. Body fat (BF) will be used to categorize children into levels of <20%, 20 – 25%, 25 – 30% and >30%. BMI will be used to define a child as acceptable body composition (ABC), OW or OB. For the purpose of this risk classification system children who are not OW and < 20 % BF are considered ABC; with the understanding that ABC does not mean optimal body composition (i.e. an 'ideal' body composition – that representing least risk for disease - has not been proposed for children). The establishment of ideal BC, although necessary, is beyond the scope of the present study. Children who are at risk for chronic disease due to body composition will be identified as those classified as > 20 % BF, OW or OB. Children classified as OW and OB will be compared to current Canadian statistics. The relationship between BF and BMI (the sensitivity and specificity of BMI compared to BF) will be examined within this sample.

Objective 3:

A third objective is to combine the PA and BC classifications (PA*BC) to provide risk classification for disease and sub-optimal development. Various levels of risk will be proposed (very low, low, moderate and high) based upon individual PA and BC measures rather than merely a binary system of "at risk" and "not at risk". Differences in PA and BC between grades and sexes will be examined. The relationship between PA (intensity and duration) and BC will be explored. K – means cluster analysis will be used to validate the proposed risk classes.

Hypotheses

Relative to each objective, it is hypothesized that

Objective 1:

a) Using a threshold of < 3 kcal/kg/d, the percentage of children classified as physically inactive will be substantially less than that of published self report data (i.e. 57%, CFLRI, 2000 Physical Activity Monitor) (Craig et al, 2001).

b) Using ≥ 8 kcal/kg/d, the percentage of children classified as physically active will be substantially less than that of self report data (i.e. 38% of females and 48% of males, CFLRI, 2000 Physical Activity Monitor), objective measurement of PA will demonstrate that less than 20% of children will actually meet or exceed the PA guidelines.

c) Approximately 50 % of children will exceed the inactive threshold (< 3 kcal/kg/d) but fail to meet or exceed the active threshold (≥ 8 kcal/kg/d) when physical activity is measured by objective means. This will demonstrate that the use of objective data provides sufficient sensitivity and specificity to identify and properly classify children who surpass the inactive threshold but fail to meet the active threshold.

Objective 2:

a) Body fat and BMI will be highly correlated measures of body composition.

b) The OW and OB percentages based upon BMI will be similar to that of Canadian data (approximately 30% and 10% respectively).

c) BMI will be a less sensitive measure of body composition when compared with BF.

Objective 3:

a) When physical inactivity is used in addition to BF and BMI as a measure to classify risk, the percentage of children identified will greater than double; classifying up to 90% as "at risk for chronic disease and sub-optimal development".

b) There will be a significant inverse relationship between physical activity level and body composition.

c) As demonstrated in previous literature in this age group, males will be generally more active than females. Body composition will not vary between sexes due to the pre-pubertal status of the sample. K – means cluster analysis will partially validate the proposed risk classification scheme.

Methods

Design and Subjects

This study was a three year mixed longitudinal and cross sectional study. The longitudinal data will not be reported on within this study. This sample consists of third, fourth and fifth grade children from ethnically diverse, low socioeconomic (SE) schools. The schools were comprised of one rural school, one urban school and two suburban schools. Two of the schools had daily physical education and two of the schools had physical education every other day. A total of 419 third, fourth and fifth grade children (males n=204 females n=215) were involved over the three year duration of the study. Children in grades 3-5 were chosen specifically to obtain measures of pre-pubertal children. This sample consisted of children free from any physical disability which would prevent or severely limit physical mobility or physical activity. Informed consent was obtained from each child's legal guardian prior to the initiation of the study. This study was approved by the Ethics Committee of the University of Manitoba, Faculties of Physical Education and Nursing.

Measures

Body Mass Index

Height in meters (m) and body mass in kilograms (kg) were measured for each child by two separate investigators for each year in study. The average of the two measures was used in data analysis. Body mass index (BMI: kg/m^2) was calculated as the division of body mass (kg) with height squared (m^2).

BMI Thresholds

BMI of the children was used to classify each child as ABC (acceptable body composition), OW (overweight) or OB (obese) using the international standards developed by Cole et al (Cole, Bellizzi et al. 2000). These standards were developed using data from six large (n > 10,000) national cross sectional growth studies on children ranging from birth to 18 years. For each national dataset, centile curves were developed identifying age dependant BMI values to define OW and OB thresholds in children corresponding to OW and OB definitions for adults of 25 kg/m^2 and 30 kg/m^2

respectively. The national centile curves were combined, providing an internationally representative centile curve with BMI thresholds for OW and OB for ages 2 to 18 in half year increments. The average age of children in grades 3, 4 and 5 are 8, 9 and 10 years. Cole and colleagues recommend when age groupings of one year are used within a study (which effectively occurs as children are grouped by grade), the respective mid year value should utilized. Therefore the BMI threshold values for 8.5, 9.5 and 10.5 years of age were utilized.

Body Fat

Triceps and calf skin folds (mm) were measured (according to American College of Sports Medicine – ACSM - guidelines) using skin fold calipers (Harpenden). Triplicate measures were taken on each child at each site, by two investigators. Skin fold measures were averaged and entered into the Slaughter skin fold equation (Slaughter, Lohman et al. 1988) to determine body fat (%). Studies have demonstrated a 0.82 ($p < 0.0001$) correlation between the Slaughter equation and DEXA derived body fat measures in children (Nicholson, McDuffie et al. 2001) and report reliability of 0.98 – 0.99 ICC and validity of 0.79 – 0.99 ICC (Janz, Nielsen et al. 1993). The Slaughter equation has been found to be superior to other published equations for children of the ages included in this study (Wong, Stuff et al. 2000), having significant correlation with body fat as measured by DEXA (De Lorenzo, Bertini et al. 1998).

Body Fat Thresholds

Widely accepted body fat definitions for OW and obesity in children are lacking. Further, few studies are available linking disease risk factors to BF in children. Takahashi and colleagues (Takahashi, Hashimoto et al. 1996) identify 20% and 25% as thresholds above which boys and girls (regardless of BMI class) had significant increases in CV risk factors. Schaefer and colleagues performed a cross-sectional study in 1989-90 on 2554 German children ages 6-19 (Schaefer, Georgi et al. 1998) and developed centile curves similar to those used for BMI by Cole. A summary of the 75th, 90th and 97th centiles for boys and girls using ages 8.5, 9.5 and 10.5 years is presented in Table 1. Based upon the data from these two studies, (Takahashi, Hashimoto et al. 1996; Schaefer, Georgi et al.

1998), the following thresholds and ranges for BF were used for both males and females across grades;

i) <20%;

ii) 20-24.99%;

iii) 25-29.99%;

iv) >30%,

Table 1: Body fat (%) for 75th, 90th and 97th centiles, males and females ages 8.5, 9.5 and 10.5 years. Data derived from Schaefer et al (1998).

Male Age (yrs)	75th	90th	97th	Female Age (yrs)	75th	90th	97th
8.5	16	20	27	8.5	18	22	27
9.5	17	23	31	9.5	20	24	29
10.5	19	25	35	10.5	21	25	31

Physical Activity

Physical activity was measured using triaxial accelerometry (RT3, www.stayhealthy.com) on approximately 60% (n=251) of the total sample (N=419). Accelerometry has been shown to be a valid measure of activity in the age category involved in this study (Eston, Rowlands et al. 1998; Rowlands, Thomas et al. 2004). The RT3 is a pager sized device that uses triaxial accelerometry technology to detect and record acceleration in the x, y and z planes. Recording mode was set at one minute epoch, which records summed acceleration values (the acceleration resultant vector and magnitudes in x, y, and z planes) for each 60 second period of time worn. Increased accelerations are detected with increasing intensity of activity. These acceleration sums are stored as “activity counts”, and from the 3 planes a resultant vector magnitude is computed ($Vm = [x^2 + y^2 + z^2]^{0.5}$) (Powell and Rowlands 2004). A proprietary (Stayhealthy.com) predictive equation is used to convert minute summed acceleration values into energy expenditure values. User information (age, height, mass, gender, name / identification code) is input (see Table 2) into the device prior to donning through a computer interface. All accelerometry data is time and date stamped. The retention of user information within the unit prevents mislabeling of data, and provides information necessary for the proprietary software algorithm for the calculation of energy expenditure.

Basal metabolic rate (BMR), and estimated values for calories expended due to activity (ACTCal) and total calories expended (TACal = BMR + ACTCal) are generated through software algorithms. The RT3 accelerometer software calculates basal metabolic rate (kcal/min) using a predictive equation based on age, body mass and gender. ACTCal are derived through the use of an algorithm applied to the resultant vector magnitude. The algorithm for the calculation has been obtained for the purposes of verification within this dataset; however non-disclosure agreements have been signed preventing the public disclosure of these algorithms.

Accelerometers, in general have known limitations such as decreased ability to portray the caloric cost of activities such as cycling and weight training (McDonald, Widman et al. 2005), or when carrying a pack or lifting objects (since the added mass is not accounted for). However, a benefit of accelerometry is the ability to monitor increases in intensity of activity; specifically the RT3 has demonstrated significant increases in vector magnitude, total energy expenditure (EE) and activity EE with increased speeds performed by an individual on a treadmill (King, Torres et al. 2004). A criticism of some accelerometers is that the units of measurement (if reported in counts per minute) are not well defined, and are not easily related to recognizable activity (i.e. slow walking, brisk walking, running) and are therefore the relevance of results are difficult to interpret (McDonald, Widman et al. 2005). The RT3 uses the activity counts to compute and display ACTCal and TACal in kcal/min, providing a recognizable measure of activity intensity. Our internal validity assessments (unpublished data) of the RT3 included verification of energy expenditure against increasing number of repetitions of squats ($n =$ 1 to 50 increments of 1, $r = 0.98$, $p < 0.01$). As well, strong correlation was demonstrated ($r = 0.96$) between energy expenditure values assessed by the RT3 accelerometer and the ACSM predictive equations for walking and running, treadmill speeds from 2 to 9 mph.

For the application of the accelerometers in this study, investigators went to the schools, fastened the units to the children and provided instructions to the children and caregivers regarding wear and use of the instrument. The device was secured in a fanny pack which was affixed around the child's waist. All of the physical activity data was recorded during weekdays. The device was worn a minimum of one day, and a maximum of four non-consecutive days, through repeated trials on a sub-sample of children. The majority of repeated accelerometry trials were performed in separate months on the same child to decrease seasonal bias on physical activity levels and patterns. Analysis was performed to evaluate differences, if any, in repeated accelerometry measures.

Table 2: Header information from accelerometer data file showing accelerometry user information, including equation estimated basal metabolic rate (AMR).

Device Info:	RT3	
ATR Serial#	B0001751	
ATR Hardware Rev	0.1	
ATR Firmware Rev	0.6	
ATR CoBrand	0	
User Info:		
User ID	Sgt1rm2602BD	
User Height	127	Cm
User Weight	28.6	Kg
User Age	8	
User Gender	0	Male
User AMR	0.7893	Calories per Minute
Test Info:		
Notes		
Activity Data:		
Download Time	03/14/2002	11:15:52
Start Time	03/13/2002	9:14:00
Format	3	XYZ 1 Minute
Number Readings	1531	

Data Analysis & Reduction

The entire sample dataset was manually checked. The numbers were visually inspected (numerically and graphically) for data entry errors prior to analysis. The data was coded by grade, year, sex, school, and date.

All accelerometry data was downloaded using accelerometer software and then exported into a spreadsheet (Microsoft Excel). Each accelerometer file was processed using a custom automated activity analysis template, specifically designed to provide a detailed analysis of each activity profile. As there is currently no available software to provide the detailed analysis of accelerometry data desired for this study, this template was developed at the University of Manitoba Human Performance Laboratory to fulfill that purpose. The development of the automated activity analysis template and threshold / classification justifications are shown in Appendices A and B.

Automated Activity Analysis Template

The automated activity analysis template performs two main functions. One is to identify total minutes of activity at each of four levels of activity intensity (inactive, obligatory, moderate, and vigorous – see Appendix A). The second function is to identify continuous bouts (CB) of activity above a predefined intensity threshold and provide characteristics of each CB (duration, average intensity, frequency and time of occurrence). This enables description of patterns of activity for an individual child, as well as characterization and comparison of activity patterns based upon activity levels, body composition, grade and sex. This activity analysis template automatically provides a physical activity assessment for each child based upon energy expenditure and a separate assessment based upon active time in moderate to vigorous intensity physical activity. Please see Appendix A for activity analysis template methodology.

Physical Activity Classification

Physical activity classification within this study was based upon a combination of guidelines jointly developed by Health Canada and CSEP, as well as guidelines used by the Canadian Fitness and Lifestyle Research Institute (CLFRI). Health Canada (www.phac-aspc.gc.ca/pau-uap/paguide/child_youth/index.html) and CSEP (www.csep.ca/physical_activity_guide.asp) together developed PA guidelines for children incorporating two separate measures; energy expenditure from physical activity as well as time spent in moderate and vigorous intensity activity (respectively referred to as "EE" and "active time" within this study). The EE guidelines require a minimum energy expenditure of 8 kilocalories per kilogram of body mass per day (kcal/kg/d), for a child to be "active enough for health benefit" (http://www.phac-aspc.gc.ca/pau-uap/paguide/child_youth/children/activityStats.html). The Canadian Fitness and Lifestyle Research Institute (CLFRI) references thresholds of less than 3 kcal/kg/d for a child to be classified as "inactive" and 6-8 kcal/kg/d to be deemed active. (http://www.cflri.ca/cflri/pa/surveys/2001survey/2001survey.html). Note the gap between "inactive" and "active" (i.e. between 3 – 6 kcal/kg/d). This level of activity is currently not labeled or described within the literature. This is an issue addressed within the present study.

The "active time" based HC / CSEP PA guidelines are for a child to achieve 90 minutes of PA (60 minutes moderate and 30 minutes vigorous intensity) per day on most days of the week. This is recommended through increasing activity progressively over a period of up to five months for those children who are currently not meeting this threshold. A concurrent time based recommendation from HC / CSEP is to decrease inactive time by 90 minutes (again over a five month period for those who are not currently considered "active"). While it is recognized that this is essentially a recommendation for 180 minutes of active time, for the purposes of this study, the 90 minute moderate and vigorous intensity "active time" will be the requirement assessed.

Table 3: Summary of Canadian physical activity guidelines for children that are referenced within this study.

Summary	Active	Inactive
HC / CSEP (EE)	≥ 8 kcal/kg/d	Not defined
HC / CSEP (time)	≥ 90 minutes (mod/vigorous intensity)	Not defined
CFLRI	≥ 6 – 8 kcal/kg/d	< 3 kcal/kg/d

Each child was classified according to their accelerometry measured PA, at thresholds formed to parallel the above Canadian PA recommendations. Thus, children were classified according to two PA schemes; accumulated energy expenditure "EE" (kcal/kg/d) and time spent participating in moderate and vigorous intensity activity "active time" (minutes). The thresholds and their respective classification label are as follows:

Accumulated Energy Expenditure

Using EE, children are categorized into one of four categories:

1. <3 kcal/kg/d (inactive, "IA")
2. 3 – 5.99 kcal/kg/d (very low active "VLA"),
3. 6 – 7.99 kcal/kg/day (low active, "LA")
4. ≥ 8 kcal/kg/d (active enough for health benefits "ACT").

Daily Time Spent in Moderate Activity

Four separate categories were also created for time spent in moderate and vigorous activity (activity time); the duration of each bout of activity above moderate intensity was determined in 1 minute intervals:

1. < 30 min
2. 30 – 59.9 min
3. 60 – 89.9 min
4. ≥ 90 min.

Please see Appendix B for detailed explanations and definitions of the above thresholds of classification.

Risk Classification Scheme

The final "risk for disease and sub-optimal development" classification schemes were completed based upon a combination of the two measures of body composition, BF and BMI; and separately for the two measures of PA, EE and active time. Risk labels "very low", "low", "moderate" and "high" as presented in Table 4 are assigned to each category of the classification. A sample summary defining the percentage of children in each risk categories was defined. The lowest levels of PA and highest levels of BC were designated "high risk". Moderate and low risk was assigned to the classes with progressive increases in PA and decreasing BC value. The class of children that met the PA recommendations and had ABC values was deemed to be at "very low risk" of development of chronic disease and sub-optimal development. Note that even within the "PARK" category (shaded cells – those with ABC but not surpassing "active" threshold) there is a range of risk values from low to high.

Table 4: Risk levels assigned to classification scheme. Risk levels (very low, low, moderate and high) represent increasing risk for disease with increasing body composition measure and decreasing physical activity measure.

PA	BC BMI – ABC BF <20%	OW 20-25%	OW 25-30%	OB >30%
Inactive	High	High	High	High
Very Low Active	Moderate	Moderate	Moderate	High
Low Active	Low	Low	Moderate	High
Active	Very Low	Low	Moderate	High

Assumptions underlying the Risk Classification Model

The risk classification scheme presented represents a model for risk for disease, providing levels of very low risk, low risk, moderate risk and high risk for chronic diseases based upon physical activity and body composition. Due to the need for further investigation in this area, several assumptions had to be made to develop this risk model. The assumptions made based upon the best available literature, and are as follows:

a) Physical activity and body composition are equally weighted risk factors (i.e. there is insufficient literature to conclude whether suboptimal body composition or insufficient physical activity represent a greater risk for disease, thus these parameters represented equal weight for disease risk).
b) Physical activity intensity is more important for health benefit than time spent in physical activity alone. A combined factor of physical activity time and intensity was used within this model.
c) The dose-response relationship between physical activity, body composition and disease risk / health benefit is linear. While several relationships for these parameters have been proposed, the true dose-response relationship between these parameters has yet to be determined. However within the ranges of physical activity and body composition used for this risk model, improved health has been demonstrated with increases in physical activity and decreases in body fat and BMI, thus for the purposes of this model a linear relationship was assumed.

Statistical Analysis

Data was input from Excel to SPSS version 11.0 for Windows (www.spss.com). Repeated measures analysis was performed for the repeated accelerometer trials to determine if within subject between trials differences existed. Normalcy was tested (PP plots) for both BC and PA parameters.

Frequency analysis was utilized to classify children by BC and by PA to allow comparison of our sample to current Canadian statistics, while associated descriptive statistics were derived for each category. Sensitivity and specificity of BMI relative to BF was determined through the use of descriptive statistics to define percent agreement of the measures.

Analysis of variance was used to test for differences in BC (height, mass, BF and BMI) between the entire sample (N = 419) and the sub-set with PA measures (n = 251). Univariate analysis of variance (ANOVA) was also utilized to test for differences in BC and PA between grades and sexes, and also to test for significant differences in BC between PA (EE and active time) classifications. Error bar plots were used to graphically display observed differences and trends.

Pearson's correlation analysis was conducted to test the significance of the relationship between BMI and BF, and the relationship between PA measured relative to body mass (kJ/kg/d) and fat free mass (kJ/kgFFM/d).

Thresholds used for body composition and activity were developed using literature for the classification of children by BC and PA. As a method to examine the natural clustering the data, k-means cluster analysis with n = 5 groups was applied to partially validate the classification method and thresholds. K – means cluster analysis requires that the investigator has a predetermined concept of what they will find in their data. The investigator determines the number of groups that the analysis should form ("k") and the variables by which to form them. The analysis uses an iterative approach to find "k" groups that are comprised of sufficiently similar individuals within the group and different individuals between groups. The *means* of the variables used to form the groups are then displayed with an F value to display the significance of each factor toward the final grouping (http://www.statsoft.com/textbook/stcluan.html). K-means analysis was used to partially validate the chosen risk classification thresholds.

Results

The results are organized with the presentation of subject demographics followed by examination and classification based upon;

1. body composition
2. physical activity
3. physical activity and body composition.

Subject Demographics

Subject characteristics are summarized based upon grade and sex in Table 5.

Table 5: Subjects characteristics (mean, SD) based upon grade and sex (M – Males, F- Females); sample size per group, age, height, body mass, body fat (BF) and body mass index (BMI). Total N = 419.

	N	Age (yr)	Height (cm)	Body Mass (kg)	BF (%)	BMI (kg/m^2)
Grade 3	191	8	132.8 (6.0)	31.1 (6.5)	20.1 (7.4)	17.55 (2.86)
M	94		132.7 (6.0)	30.4 (6.3)	17.3 (7.2)	17.15 (2.64)
F	97		132.8 (6.0)	31.8 (6.7)	22.7 (6.6)	17.94 (3.02)
Grade 4	133	9	138.0 (6.5)	35.8 (10.0)	21.4 (8.1)	18.58 (4.14)
M	62		138.7 (6.5)	34.8 (8.6)	19.2 (7.9)	17.95 (3.25)
F	71		137.5 (6.6)	36.6 (11.1)	23.5 (7.8)	19.12 (4.74)
Grade 5	95	10	143.1 (7.7)	40.9 (12.4)	23.5 (8.8)	19.71 (4.75)
M	49		143.4 (8.2)	40.7 (11.0)	22.9 (8.9)	19.59 (3.86)
F	46		142.8 (7.2)	41.0 (13.8)	24.2 (8.8)	19.84 (5.59)

*BF data missing for n = 1 (male, grade 5)

Analysis of variance (Table 6) demonstrated a significant increase in height, body mass, BF and BMI with an increase in grade. Females had significantly higher BF than males and while BMI was higher in females, the difference just failed to reach statistical significance (p = 0.055).

Table 6: Results of analysis of variance based upon grade and sex as independent factors in the ANOVA. Significant differences are shaded (p< 0.05). No interaction was observed between grade and sex (G*S).

	Grade	Sex	G*S
Height	0.001	0.378	0.700
Mass	0.001	0.230	0.828
BF	0.001	0.001	0.095
BMI	0.001	0.055	0.657

Body Composition

Using previously described thresholds for BF and BMI, the sample was classified separately by each measure (BF - see Table 7, BMI – see Table 8). The interrelationship between BF and BMI was explored, and subsequent to this the sensitivity and specificity of BMI was assessed relative to BF. Note that the overweight category in Table 8 includes obese individuals ("OW +").

Table 7: Classification of sample [n, (%)] based upon grade, sexes combined and sexes separately; males (M) and females (F), using BF thresholds of <20%, 20-25%, 25-30% and >30%. Percentages based upon grade totals and then on sex totals.

	<20%	20-25%	25-30%	>30%
Grade 3	111 (58.1)	37 (19.4)	19 (9.9)	24 (12.6)
M	68 (72.3)	13 (13.8)	5 (5.3)	8 (8.5)
F	43 (44.3)	24 (24.7)	14 (14.4)	16 (16.5)
Grade 4	73 (54.9)	23 (17.3)	14 (10.5)	23 (17.3)
M	43 (69.4)	7 (11.3)	3 (4.8)	9 (14.5)
F	30 (42.3)	16 (22.5)	11 (15.5)	14 (19.7)
Grade 5	41 (43.6)	18 (19.1)	14 (14.9)	21 (22.3)
M	21 (50.0)	12 (24.4)	5 (11.9)	10 (23.8)
F	20 (38.5)	6 (12.2)	9 (17.3)	11 (21.2)

Table 8: Classification of sample [n (%)] based upon grade and BMI (ABC = acceptable body composition, OW + = overweight and obese, OB = obese). Recall that OW and OB thresholds change with grade. Classification based upon grade, sexes combined and sexes separately; males (M) and females (F). Percentages based upon grade totals and then on sex totals.

		ABC	OW +	OB
Grade 3		138 (72.2)	53 (27.7)	13 (6.8)
	M	73 (77.6)	21 (22.3)	6 (6.4)
	F	65 (67.0)	32 (33.0)	7 (7.2)
Grade 4		95 (71.4)	38 (28.6)	20 (15.0)
	M	49 (79.0)	13 (21.0)	6 (9.7)
	F	46 (64.8)	25 (35.2)	14 (19.7)
Grade 5		59 (62.1)	36 (37.9)	13 (13.7)
	M	31 (63.3)	18 (36.7)	6 (12.2)
	F	28 (60.9)	18 (39.1)	7 (15.2)

A significant positive correlation ($r=0.83$, $p < 0.05$) was found between BF and BMI as illustrated in Figure 1.

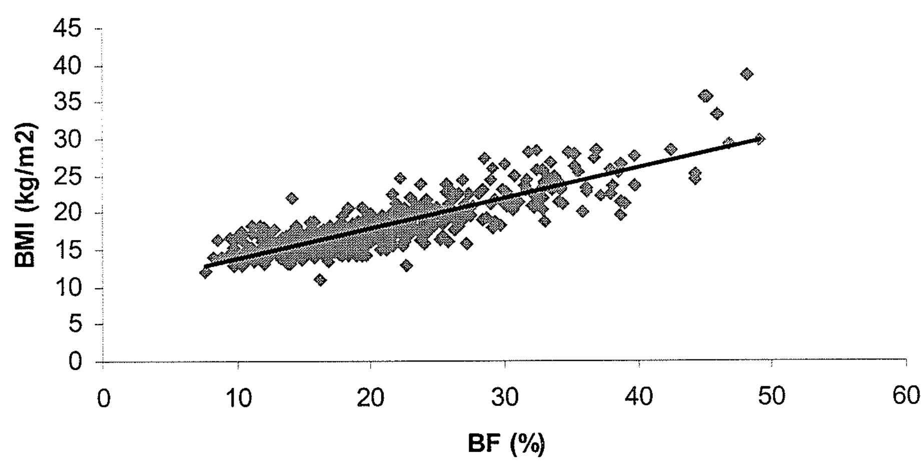

Figure 1: Correlation between BF and BMI (n=419, r=0.83, p<0.05).

Sensitivity and Specificity of BMI

The sensitivity and specificity of BMI was examined relative to the varying thresholds for skin fold assessed body fat. Specifically, the threshold(s) of BF at which BMI attained its highest specificity and sensitivity when classifying a child as OW or OB was assessed.

If a measure is sensitive, it is able to properly identify a positive result (i.e. if BMI is sensitive it will appropriately classify children who have "high" body fat as OW or OB). If a measure is specific, it will not identify a negative (absent) result (i.e. if BMI is specific, a child with acceptable levels "< 20%" of BF will not be classified as OW or OB). The percentage of type I errors (BMI classifies a child as at risk when BF did not) and type II errors (BMI failing to identify a child classified as at risk by BF) were compared for BMI relative to BF as the reference standard. This assumes that skin fold assessed BF is a criterion measure of body fatness.

The following conditions were utilized to determine the threshold(s) of BF at which BMI attained highest specificity and sensitivity when classifying a child as OW or OB:

i) > 20% BF, OW BMI
ii) > 25% BF, OW BMI
iii) > 25% BF, OB BMI
iv) > 30% BF, OB BMI

BMI demonstrated highest sensitivity (see Table 9) when >25% BF was considered OW, and the highest specificity when >25% BF was considered OB. Combined sensitivity and specificity were highest (lowest combined error rate) when > 25% BF was considered OW.

Table 9: Report of BMI sensitivity and specificity, type I and type II error rate, combined sensitivity and specificity (S&S), and overall error rate (Error) using different body fat thresholds and BMI classifications (OW and OB). The shading represents the level at which BMI had highest S&S with respect to BF (> 25%).

BF threshold	BMI threshold	Sensitivity	Specificity	Type I	Type II	S&S	Error
> 20%	OW	55.60%	93.30%	6.70%	44.40%	74.40%	25.60%
> 25%	OW	73.25%	87.80%	12.20%	26.80%	80.50%	19.50%
> 25%	OB	35.20%	97.80%	2.20%	64.80%	66.50%	33.50%
> 30%	OB	55.30%	96.20%	3.80%	44.70%	75.60%	24.30%

A further exploration of the relationship between BMI and BF thresholds was performed based upon the results shown in Table 9. Classification of children using two thresholds of body fat; (25 and 20%) are shown in Tables 10 and 12. Classification of children using BMI threshold of ABC and OW+ is presented in Table 11 to allow comparison the two thresholds for BF classification. As demonstrated with specificity and sensitivity assessment, the percentages of children classified by BF and BMI as "at risk due to body composition" is in greater agreement when > 25% BF (Table 10) and OW BMI (Table 11) are used as the respective thresholds for BC risk within the sample. Considering all children over > 25% BF or all children OW+ (BMI) would classify 23% and 28% of third grade children as at risk respectively, 28% and 29% of fourth grade children and 37% and 38% of fifth grade children as at risk. Comparing these results with a BC risk classification utilizing >20% BF as a threshold for disease risk (Table 12), a greater discrepancy is apparent between percentages classified by BF and BMI. Using the > 20% BF threshold, 42% of 3rd grade children are at risk for disease due to BC, 45% of fourth grader children and 56% of fifth grade children.

Table 10: Number (%) of children classified as acceptable body composition (ABC) and over fat (OF) using a 25% BF threshold.

Body Fat		ABC <25%	OF >25%
Grade 3		148 (77.5)	43 (22.5)
	M	81 (86.2)	13 (13.8)
	F	67 (69.1)	30 (30.9)
Grade 4		96 (72.2)	37 (27.8)
	M	50 (80.6)	12 (19.4)
	F	46 (64.8)	25 (35.2)
Grade 5		59 (62.8)	35 (36.8)
	M	33 (67.3)	15 (30.6)
	F	26 (56.5)	20 (43.4)

Table 11. Number (%) of children classified by BMI as ABC or OW+ (OW or OB) using the BMI OW threshold (Cole, Bellizzi et al. 2000)for risk classification.

BMI		ABC	OW +
Grade 3		138 (72.3)	53 (27.7)
	M	73 (77.7)	21 (22.3)
	F	65 (67.0)	32 (33.0)
Grade 4		95 (71.4)	38 (28.6)
	M	49 (79.0)	13 (21.0)
	F	46 (64.8)	25 (35.2)
Grade 5		59 (62.1)	36 (37.9)
	M	31 (63.3)	18 (36.7)
	F	28 (60.9)	18 (39.1)

Table 12: Number (%) of children classified as ABC and over fat (OF) when 20% BF used as threshold for risk classification.

BF		ABC <20%	OF >20%
Grade 3		111 (58.1)	80 (41.9)
	M	68 (72.3)	26 (27.6)
	F	43 (44.3)	54 (55.7)
Grade 4		73 (54.9)	60 (45.1)
	M	43 (69.4)	19 (30.6)
	F	30 (42.3)	41 (57.7)
Grade 5		41 (43.2)	53 (55.8)
	M	21 (42.8)	27 (55.1)
	F	20 (43.5)	26 (56.5)

Since it has been demonstrated that there is an increased cardiovascular risk in children who exceed 20% BF (Takahashi, Hashimoto et al. 1996), a tool used to measure and classify children by body composition should have the sensitivity to identify individuals with > 20% BF. BMI fails to consistently identify those children with 20 – 25% BF and thus BMI lacks sensitivity for use on its own to describe risk for disease.

Physical Activity

Of the entire sample of children measured, 60% had physical activity monitoring through accelerometry. A total of 125 children had repeated measures within the study; representing 440 days of physical activity data (see Table 13). Repeated measures analysis of variance was performed for children who had multiple days of accelerometry measurement. No significant difference was found between physical activity measures for repeated trials, therefore repeated trials measured within the same year were averaged for each child. A total of 251 averaged "days" of physical activity data were used in the analysis. Analysis of variance was used to test for differences in body composition measures (height, mass, BF and BMI) between the entire sample, and the subset with PA monitoring. No significant differences were observed between BC measures.

Table 13: Number of children with one, two, three and four repetitions of daily physical activity assessment from accelerometry.

Trials/child	# Trials	Total trials
1	156	156
2	99	198
3	18	54
4	8	32
Total	281	440

A summary of physical activity data derived from accelerometry assessed PA is provided in Table 14; including the following physical activity parameters:

i) AA = all physical activity (≥ 51 cal/kg/min);

ii) AC = all continuous physical activity (≥ 51 cal/kg/min, accumulated within continuous bouts);

iii) AM = all moderate intensity activity (≥ 96 cal/kg/min);

iv) CM = continuous moderate intensity activity (≥ 96 cal/kg/min, accumulated within continuous bouts);

v) SUM = minutes of accumulated moderate and high intensity activity (≥ 96 cal/kg/min);

vi) Min Mod= minutes of accumulated moderate intensity activity (96 – 143.99 cal/kg/min);

vii) Min Vig = minutes of accumulated vigorous intensity activity (≥ 144 cal/kg/min);

viii) Min/CB = average length (minutes) of continuous bout (CB);

ix) # CB = number of CB over duration worn.

It is important to note that the energy expenditure from all physical activity (AA), as well as physical activity from continuous bouts (AC) exceeds the HC / CSEP PA guideline of 8 kcal/kg/d for all grades and sexes, while energy expenditure from moderate activity (AM) or from continuous moderate activity (CM) fail to reach this threshold.

Table 14: Summary of PA measures derived from accelerometry [mean (SD)].

	N	Grade	AA*	AC*	AM*	CM*	Sum**	Min Mod**	Min Vig**	Min/ CB**	# CB Ŧ
Grade 3	145	3	17.6 (4.9)	12.7 (4.9)	5.5 (3.7)	5.4 (3.7)	35.9 (23.2)	29.0 (18.1)	6.9 (7.5)	24.6 (7.6)	8.4 (2.8)
M	78		18.3 (5.5)	13.7 (5.3)	6.6 (4.1)	6.4 (4.1)	42.2 (26.1)	33.7 (20.4)	8.5 (8.7)	26.7 (8.1)	8.0 (2.6)
F	67		16.8 (4.0)	11.5 (4.2)	4.3 (2.6)	4.2 (2.6)	28.5 (16.6)	23.5 (13.3)	5.0 (5.1)	22.1 (6.1)	8.9 (3.0)
Grade 4	61	4	17.3 (6.3)	12.0 (7.1)	5.1 (4.7)	5.0 (4.7)	32.5 (8.1)	26.2 (18.7)	6.3 (8.3)	22.6 (8.1)	8.5 (2.8)
M	24		19.3 (7.0)	14.2 (8.4)	7.0 (5.9)	6.8 (5.9)	40.0 (26.4)	30.1 (17.7)	9.9 (10.6)	24.5 (8.1)	8.3 (2.3)
F	37		15.9 (5.5)	10.6 (5.9)	3.9 (3.3)	3.7 (3.3)	27.7 (23.5)	23.6 (19.1)	4.0 (5.3)	21.3 (8.0)	8.6 (3.1)
Grade 5	45	5	19.3 (6.8)	14.1 (7.2)	6.6 (4.8)	6.4 (4.8)	40.4 (28.6)	33.1 (22.0)	6.8 (8.0)	27.1 (12.3)	7.3 (2.6)
M	28		19.8 (7.5)	14.5 (7.5)	7.0 (5.0)	6.8 (5.0)	42.7 (27.9)	33.2 (19.9)	8.7 (9.4)	27.2 (10.3)	7.1 (2.5)
F	17		18.4 (5.5)	13.6 (6.7)	5.8 (4.4)	5.7 (4.4)	36.8 (30.2)	30.4 (23.9)	4.9 (5.5)	26.9 (15.3)	7.7 (2.8)

Units: * kcal/kg/d, ** minutes, Ŧ frequency (number of continuous bouts per day)

Analysis of variance was performed to assess the effect of grade and sex on PA measures. The results are presented in Table 15. The effect of grade was not significant for all activity measures with a potential trend toward significance for average duration of continuous activity. Males had significantly higher measures of energy expenditure as measure by all physical activity (AA), all continuous activity (AC), all moderate activity (AM) and moderate continuous activity (MC). Males accumulated significantly more minutes in moderate and high intensity activity than females and had longer duration of continuous bouts. No significant difference was found between the average intensity of continuous bouts of activity between sexes.

Table 15: Differences in PA measures between grade and sex, level of significance displayed.

PA Measure	Grade	Sex	G*S
AA	0.258	0.011	0.542
AC	0.330	0.009	0.518
AM	0.361	0.001	0.489
CM	0.386	0.001	0.493
Average intensity of CB	0.669	0.600	0.172
Duration of CB (MIN/CB)	0.055	0.034	0.352
Minutes of Moderate PA	0.311	0.011	0.601
Minutes of Vigorous PA	0.950	0.001	0.402
Sum (moderate+vigorous)	0.460	0.003	0.647

Following this analysis, an ANOVA was performed to determine if there was a significant difference between sexes for the number of CB within a day. Females were found to have significantly more CB of activity within the day (females: mean = 8.6 (±3.0) CB/d; males 7.8 (±2.5) CB/d) across grades ($p = 0.021$).

Adjusting Physical Activity to Body Mass

Adjusting PA for either body mass or fat mass (i.e. expression of EE relative to either kg or kg of fat free mass) is appropriate when comparing PA between individuals (Ekelund, Yngve et al. 2004). Within this sample (Figure 2), these methods were highly correlated ($r^2 = 0.987$, $p < 0.01$). Due to the strong linearity, either mass normalization method could be employed. However in order to facilitate comparisons of the results of this study to national standards and recommendations (which are normalized to body mass, not FFM), body mass normalization of PA data was used.

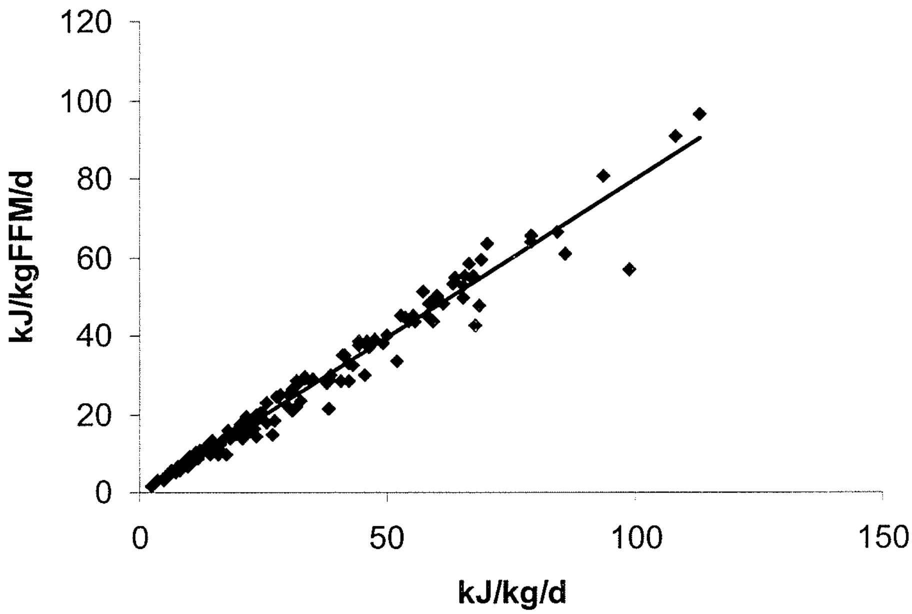

Figure 2: A strong linear correlation ($r^2 = 0.987$, $p < 0.01$) is demonstrated between PA EE expressed relative to body mass (x axis) and PA EE relative to fat free mass (y axis).

Physical Activity Classification

Physical activity assessment was performed using:

1) physical activity EE (kcal/kg/d)

2) activity time (minutes spent active).

Results of the assessment by PA EE are presented in Table 16, and results of PA active time are presented in Table 17.

Table 16: Classification of the sample [n (%)] by activity level (PA EE, kcal/kg/d), males (M) and females (F) classified individually and combined by grade, percentages based upon grade totals and then on sex. Shading highlights the active children [n (%)] for each grade combined by sex.

		Inactive	Very Low Active	Low active	Active
Grade 3		46 (31.7)	45 (31.0)	22 (15.2)	32 (22.0)
	M	21 (26.9)	18 (23.1)	13 (16.7)	26 (33.3)
	F	25 (37.3)	27 (40.3)	9 (13.4)	6 (8.9)
Grade 4		30 (49.2)	15 (24.6)	5 (8.2)	11 (18.0)
	M	8 (33.3)	6 (25.0)	4 (16.7)	6 (25.0)
	F	22 (59.5)	9 (24.3)	1 (2.7)	5 (13.5)
Grade 5		14 (31.1)	10 (22.2)	7 (15.6)	14 (31.1)
	M	7 (25.0)	7 (25.0)	5 (17.9)	9 (32.1)
	F	7 (41.2)	3 (17.6)	2 (11.8)	5 (29.4)

Classification of children by EE demonstrated that only 22% of third graders, 18.0% of fourth graders and 31.1% of fifth graders met or exceeded the physical activity EE threshold for "active enough for health benefits" of ≥ 8 kcal/kg/d – refer to shaded cells in Table 16.

Table 17: Classification of the sample [n (%)] by active time (min), males (M) and females (F) classified individually and combined by grade, percentages based upon grade totals and then on sex.

		< 30 min	30-59.9 min	60–89.9 min	90+ min
Grade 3		75 (51.2)	48 (33.1)	17 (11.7)	5 (3.4)
	M	34 (43.6)	26 (33.3)	13 (16.7)	5 (6.4)
	F	41 (61.2)	22 (32.8)	4 (6.0)	0 (0)
Grade 4		36 (59.0)	14 (23.0)	10 (16.4)	1 (1.6)
	M	10 (41.7)	8 (33.3)	6 (25.0)	0 (0)
	F	26 (70.3)	6 (16.2)	4 (10.8)	1 (2.7)
Grade 5		20 (44.4)	16 (35.6)	5 (11.1)	4 (8.9)
	M	12 (42.9)	9 (32.1)	5 (17.9)	2 (7.1)
	F	8 (47.1)	7 (41.7)	0 (0)	2 (11.8)

When active time was used for classification, even fewer children met the specific guidelines. Using the maximum threshold of 90 minutes of moderate or vigorous activity per day, 3.4 %, 1.6% and 8.9% of children were classified as active (grades 3, 4 and 5 respectively – shaded cells, Table 17). A summary of PA classification results (EE and active time, grades and sexes combined) is presented in Table 18. Discrepancy between the requirements for an individual to be considered active according to HC / CSEP EE and active time thresholds (≥ 8 kcal/kg/d and 90 minutes of moderate and vigorous activity respectively) is illustrated as 22.7% of children are "active" based upon EE and 4.0% based upon active time.

Table 18: Summary [n (%)] of PA classification grades and sexes combined; by EE (inactive, very low active, low active, active), and active time (< 30 min, 30 – 59.9 min, 60 – 89.9 min, > 90 min)

EE		Active Time	
Inactive	90 (35.9)	**< 30 min**	131 (52.2)
Very Low Active	70 (27.9)	**30 – 59.9 min**	78 (31.1)
Low active	34 (13.5)	**60 – 89.9 min**	32 (12.7)
Active	57 (22.7)	**>90 min**	10 (4.0)

To further facilitate comparison between the use of EE and activity time as PA measures within this study and between this study and other literature (published and future studies); the mean values for the following alternate PA measures are presented in Tables 19 and 20:

i) EE (*kcal/kg/d*),

ii) EE (*kJ/kg/FFM/d* -kilojoules per kilogram of fat free mass per day),

iii) minutes in moderate / vigorous intensity activity (*sum*),

iv) average intensity of CB of activity (*avg int* - cal/kg/session),

v) average length of CB in minutes (*min*/CB),

vi) number of CB / time worn (*# CB*).

With increase in PA as classified by EE and activity time, concomitant increases in the total minutes spend in moderate to vigorous activity, average intensity of each bout of activity and the duration of each bout is observed. Frequency of CB (# CB) shows a greater difference between activity time classes than between EE classes.

Table 19: PA measures summary between PA EE classes: mean (SD) physical activity measures: EE (kcal/kg/d), EE (kJ/kgFFM/d = kilojoules/kilogram of fat free mass/day), SUM = sum of minutes in moderate / vigorous intensity activity, Avg int = average intensity of CB of activity, min/CB = average length of CB in minutes, # CB = number of CB / time worn).

PA EE	kcal/kg/d	kJ/kgFFM/d	Sum	Avg Int	Min/CB	# CB
IA	1.8 (0.6)	10.0 (3.6)	14.3 (5.9)	361.9 (335.7)	20.2 (6.8)	7.5 (2.9)
VLA	4.3 (0.8)	23.1 (4.9)	30.0 (8.0)	471.6 (350.98)	23.3 (5.9)	8.7 (2.8)
LA	6.9 (0.5)	36.1 (4.8)	42.8 (10.4)	536.3 (417.9)	25.0 (6.8)	8.7 (2.8)
ACT	11.8 (3.2)	61.2 (16.7)	73.0 (17.6)	541.2 (612.4)	32.6 (10.2)	8.5 (2.4)

Table 20: PA measures summary between PA active time classes: mean (SD): EE (kcal/kg/d), EE (kJ/kgFFM/d = kilojoules/kilogram of fat free mass/day), SUM = sum of minutes in moderate / vigorous intensity activity, Avg int = average intensity of CB of activity (cal/kg/session), min/CB = average duration of CB in minutes, # CB = number of CB/d).

Active Time	kcal/kg/d	kJ/kgFFM/d	Sum	Avg.int	Min/CB	# CB
0 – 29.9 min	2.5 (1.3)	13.9 (7.0)	17.3 (6.8)	395.8 (354.6)	20.6 (6.1)	7.6 (2.9)
30 – 59.9 min	6.5 (2.0)	34.1 (10.3)	42.9 (8.8)	461.5 (344.2)	26.2 (7.6)	8.8 (2.6)
60 – 89.9 min	11.9 (3.2)	62.2 (16.9)	74.5 (7.7)	602.0 (616.2)	32.5 (8.0)	8.9 (2.4)
> 90 min	14.8 (2.7)	76.3 (14.4)	100.8 (7.2)	754.5 (910.3)	38.0 (14.5)	9.0 (2.2)

Again, the discrepancy between HC / CSEP EE active threshold ($\geq$ 8 kcal/kg/d) and the "active time" active threshold (> 90 minutes) is exposed with direct comparison of the two classifications. For instance, a child classified by EE as active ($\geq$ 8 kcal/kg/d) participates on average in 73 minutes of activity (Table 19). A child who meets the 90-minute active time threshold clearly exceeds the EE guideline, expending on average 14.8 kcal/kg/d (Table 20). Thus, using the current HC/CSEP guidelines, a child who is classified as active by EE may fail to accumulate the recommended active time at moderate and vigorous intensity PA.

The Relationship between Physical Activity and Body Composition

Dose Response Effect of Physical Activity on Body Composition

The relationship between PA and BC was examined by comparing mean BF and BMI within PA classifications (shown above) based upon EE (Figure 3) and active time (Figure 4). A significant inverse relationship was demonstrated between PA EE and BF ($p = 0.006$), as well as BMI ($p = 0.002$). A statistically significant lower activity time was observed with increases in BF ($p = 0.03$), and while BMI decreased with increasing active time, this difference failed to reach statistical significance ($p = 0.08$).

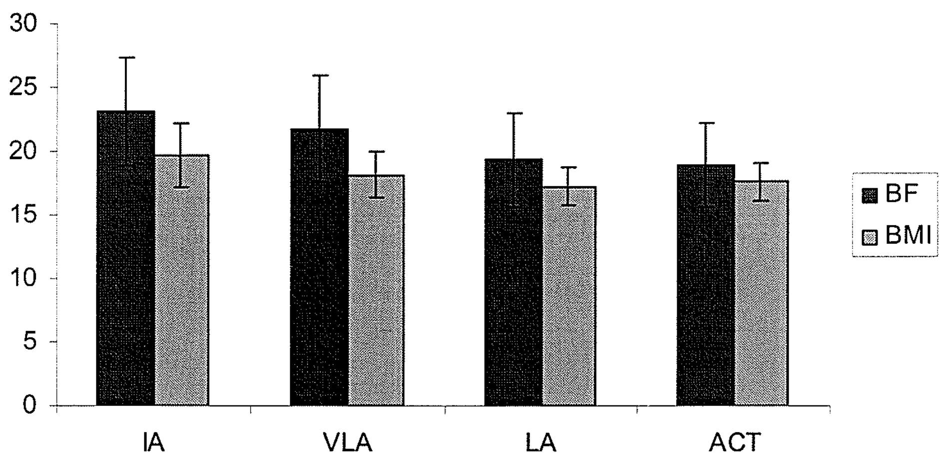

Figure 3: Mean (SD) values of BF and BMI for PA EE categories of IA, VLA, LA and ACT. A significant difference in BF (p = 0.006) and BMI (p = 0.002) was present between PA groups, demonstrating decreasing BC values with increasing activity.

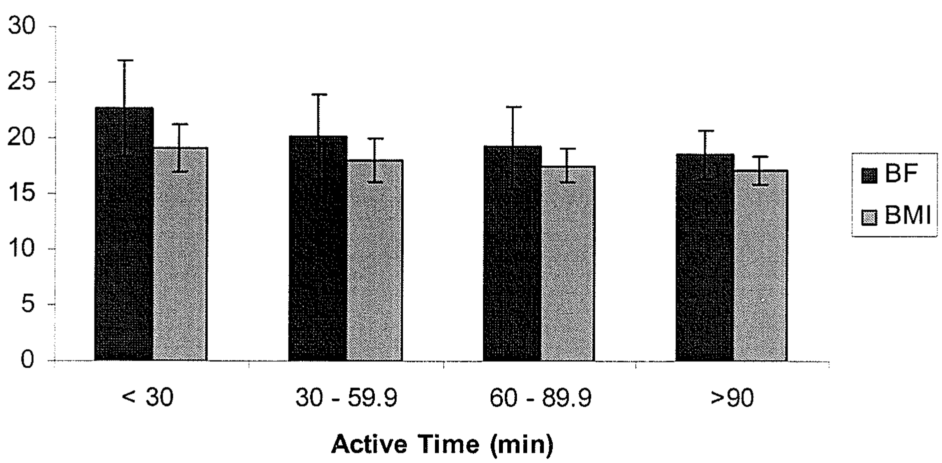

Figure 4: Mean (SD) values of BF and BMI for children as classified by "active time" (time spent in moderate / vigorous intensity PA). BF and BMI decreased in a dose response fashion to increasing active time, demonstrating decreasing BC values with increasing activity. A significant decrease of BF was demonstrated (p = 0.03) and a decrease in BMI was observed with increasing time active (NS, p =0.08).

Body Composition Values of PA classes

Mean body composition values (BF, BMI, fat mass "FM", and fat free mass "FFM") are presented for their respective PA category. PA EE classification and mean (SD) BC values are displayed in Table 21, and PA active time classification and mean (SD) BC values are displayed in Table 22. For both PA classification methods, a decrease in BF, BMI and FM is evident with increasing PA level, again supporting the dose response effect of PA. A significant difference was observed in FM between PA EE categories ($p = 0.007$). A significant difference was also present in FFM between PA EE groups ($p = 0.047$), however this was non significant once the lowest activity group (IA) was removed from the analysis ($p = 0.641$).

Table 21: Mean (SD) body composition data (BF, BMI, FFM = fat free mass, FM = fat mass), as classified by EE.

PA EE Class	BF (%)	BMI	Mass (kg)	FM (kg)	FFM (kg)
IA	23.2 (8.5)	19.7 (4.9)	37.3 (7.2)	9.2 (6.2)	27.9 (6.5)
VLA	21.8 (8.3)	18.2 (3.6)	33.8 (9.2)	7.9 (5.1)	26.0 (5.2)
LA	19.3 (7.3)	17.2 (3.1)	31.8 (8.4)	6.6 (4.0)	25.2 (5.0)
ACT	18.9 (6.5)	17.6 (3.0)	32.7 (7.2)	6.5 (3.8)	26.2 (4.4)

Similarly a significant difference was found in FM ($p = 0.039$) between time classes, while there was no significant difference in FFM ($p = 0.515$)

Table 22: Mean (SD) body composition measures (BF, BMI, FFM = fat free mass, FM = fat mass) derived for each class of active time.

Active Time	BF (%)	BMI	Mass (kg)	FM (kg)	FFM (kg)
< 30 min	22.7 (8.4)	19.1 (4.4)	35.9 (10.5)	8.7 (5.9)	27.0 (5.5)
30-59.9 min	20.1 (7.7)	18.0 (3.9)	33.7 (9.5)	7.2 (4.5)	26.4 (6.4)
60-89.9 min	19.2 (7.3)	17.5 (3.0)	31.8 (6.5)	6.4 (4.3)	25.4 (3.3)
> 90 min	18.6 (4.2)	17.1 (2.5)	32.5 (5.6)	6.1 (2.0)	26.4 (4.3)

Risk Classification based upon Physical Activity and Body Composition

Finally, as per the main purpose of this study the sample was classified concurrently by PA and BC (PA*BC) to assign risk for chronic disease and sub-optimal development. Risk classification was performed separately for EE and active time. The following classifications were performed:

1. Energy expenditure from physical activity was used with the following body composition measures to classify children

    i) BMI (Table 23)

    ii) BF (Table 24)

iii) BC (BF/BMI) (Table 25)

2. Physical activity time was used to classify children along with

i) BC (BF/BMI) (Table 26)

These classifications were based upon the criteria and thresholds established in the sections above. Comparing joint PA* BC classification using BMI (ABC – Table 23) versus BF (< 20 % - Table 24) again demonstrates that BMI underestimates risk due to BC relative to BF. Assuming ABC BMI and < 20 % BF both represent low risk due to body composition, less children overall are in the < 20 % BF category than in the ABC BMI category. This results in fewer children classified as having "low risk due to body composition" in each PA EE class. The percentage of children in each PA EE category as classified by BMI ABC and BF <20% respectively are: IA (22.7%, 15.5%), VLA (19.5%, 13.5%), LA (10.4%, 8.0%), ACT (17.9%, 16.3%).

Table 23: Risk classification [n (%)] using physical activity EE classes and BMI (ABC – acceptable body composition, OW – overweight, OB – obese).

		BMI	
PA EE Class	ABC	OW	OB
IA	57 (22.7)	15 (6.0)	18 (7.2)
VLA	49 (19.5)	14 (5.6)	7 (2.8)
LA	26 (10.4)	7 (2.8)	1 (0.4)
ACT	45 (17.9)	9 (3.6)	3 (1.2)

Table 24: Risk classification [n (%)] using physical activity EE classes and BF (< 20%, 20 – 25%, 25 – 30% and > 30%).

		BF		
PA EE Class	<20 %	20-25 %	25-30 %	>30 %
IA	39 (15.5)	17 (6.8)	17 (6.8)	17 (6.8)
VLA	34 (13.5)	16 (6.4)	8 (3.2)	12 (4.8)
LA	20 (8.0)	6 (2.4)	4 (1.6)	4 (1.6)
ACT	41 (16.3)	7 (2.8)	4 (1.6)	5 (2.0)

When BF and BMI were combined to provide a BC classification for a child, the measure that represented greater risk for the child was used, acknowledging that this places more children at risk than if either measure was used alone. Risk classification based upon PA EE and BC (BMI and BF) clearly displays the PARK group (see shaded cells – Table 25). These children would not be identified as at risk for disease and sub-optimal development based upon their BC (BMI ABC and BF <20%), however are at risk due to insufficient accrual of PA (< 8 kcal/kg/d).

Table 25: Risk classification [n (%)] of sample using body composition (BMI, BF) and physical activity EE. Shaded cells indicate "PARK" class (n = 87, 34.7% of sample).

PA EE Class		BMI - ABC BF <20%	OW 20-25%	OW 25-30%	OB >30%
Inactive		35 (13.9)	17 (6.8)	21 (8.4)	17 (6.8)
	M	21 (16.2)	4 (3.1)	5 (3.8)	6 (4.6)
	F	14 (11.6)	13 (10.7)	16 (13.2)	11 (9.1)
Very Low Active		32 (12.7)	18 (7.2)	8 (3.2)	12 (4.8)
	M	18 (13.8)	6 (4.6)	2 (1.5)	5 (3.8)
	F	14 (11.6)	12 (9.9)	6 (5.0)	7 (5.8)
Low Active		20 (8.0)	6 (2.4)	4 (1.6)	4 (1.6)
	M	14 (10.8)	5 (3.8)	1 (0.8)	2 (1.5)
	F	6 (5.0)	1 (0.8)	3 (2.5)	2 (1.7)
ACT >8 kcal/kg/d		38 (15.1)	10 (4.0)	4 (1.6)	5 (2.0)
	M	28 (21.5)	6 (4.6)	3 (2.3)	4 (3.1)
	F	10 (8.3)	4 (3.3)	1 (0.8)	1 (0.8)

Table 26: Risk classification [n (%)] of sample using body composition data (BMI, BF) and physical activity time. Shaded cells indicate "PARK" class (n=118, 47.0%of sample).

		BC		
PA Active Time	**BMI - ABC BF <20%**	**OW 20-25%**	**OW 25-30%**	**OB >30%**
0 - 30 min	53 (21.1)	31 (12.4)	17 (6.8)	30 (12.0)
30 – 60 min	43 (17.1)	13 (5.2)	10 (4.0)	12 (4.9)
60 – 90 min	22 (8.8)	5 (2.0)	1 (0.4)	4 (1.6)
> 90 min	7 (2.8)	2 (0.8)	1 (0.4)	0 (0)

Risk level was assigned to each category of the risk classification schemes (very low, low, moderate and high – as described in Table 4). Only 15.1% of this sample was classified as having very low risk of chronic disease based upon PA (EE) and BC, while 2.8% were at low risk based upon PA (AT) and BC (Table 27). Ultimately, the remaining 84.9 – 97.2% of children are classified as at risk based upon insufficient PA and body composition.

Table 27: Percentage of sample classified into each of the four risk categories using the two methods of combined classification (by BC*PA EE activity level and BC*PA activity time).

Risk	BC*EE	BC*Active Time
High	44.2%	58.6%
Moderate	26.3%	27.1%
Low	14.3%	11.6%
Very Low	15.1%	2.8%

K – means Cluster Analysis

K – means cluster analysis is a method to evaluate natural mathematical clustering of variables within a data set. The mathematical clusters formed were compared for validation purposes with the categories produced using rationalized thresholds for BC and PA. K-means cluster analysis was performed by entering the body composition variables (BF, BMI) and PA variables (EE, active time). This analysis identifies subjects which naturally cluster together in a predefined k = 5 groups. The cluster sizes (% of sample) and mean values for BF, BMI, EE (kcal/kg/d), and active time (minutes at moderate and above intensity) are presented in Table 28.

Table 28: Percent of sample classified into respective groups by K-means analysis. Mean values [BF, BMI, EE – kcal/kg/d, active time (minutes in moderate / vigorous intensity activity)] for groups 1 – 5 identified by K-cluster analysis.

	% of sample	BF	BMI	EE (kcal/kg/d)	Active Time (min)
Group 1	34.0	17.8	16.75	2.9	19.3
Group 2	18.6	31.6	22.6	2	14.5
Group 3	25.9	20.6	18.35	6.3	41.1
Group 4	14.2	19.3	17.44	10.1	66.7
Group 5	7.3	17.6	16.91	15	93.7

The risk classification scheme was partially validated by the groups identified by K – means cluster analysis as the naturally occurring groups parallel the risk groups of the proposed classification scheme. Note the dose response effect of increasing PA and decreasing BC in groups 2 – 5. The lowest mean PA measures (Group 2; EE: 2.0 kcal/kg/d, active time: 14.5 minutes) correspond with the highest mean measures of BC (BF: 31.6%, BMI: 20.6 kg/m^2). The highest mean PA measures (Group 5; EE: 15 kcal/kg/d, active time: 93.7 min) correspond with the lowest mean BC measures (BF: 17.6%, BMI: 16.91 kg/m^2). This was also demonstrated in the proposed risk classification scheme, using both PA EE and active time. Using PA*BC (EE) classification (Table 21), mean BF decreased with increased activity. Comparing the inactive category to the active category, mean BF decreased from 23.2% to 18.9 % and mean BMI decreased from 19.7 kg/m^2 to 17.6 kg/m^2. The same trend was observed with PA*BC (active time) (Table 22) with mean BF decreasing from 22.7% to 18.6 % and mean BMI decreasing from 19.1 kg/m^2 to 17.1 kg/m^2.

Risk due to BC and PA was assigned to K – cluster groups 1 – 5 (Table 29). K – means analysis classifies 34.0 % of the sample in the PARK category. Similarly, BC and PA (EE and active time respectively) classify 34.7 % (Table 25 – shaded cells) and 47.0% into this category. Likewise, K-means analysis identifies 7.3 % of children to be at "very low risk" due to PA and BC (Table 29), while 2.8% and 15.1% of the sample are at "very low risk" due to PA / BC (active time and EE respectively).

Table 29: Classification of groups 1 – 5 as identified by K – means cluster analysis. Risk assessed separately for BC and PA; final classification provided based upon combination of BC and PA risk.

	% of sample	BC – Risk	PA – Risk	Classification
Group 1	34.0	Very Low	High	"PARK"
Group 2	18.6	High	High	High Risk
Group 3	25.9	Moderate	Low	Low – Moderate
Group 4	14.2	Low	Very Low	Very Low – Low
Group 5	7.3	Very Low	Very Low	Very Low

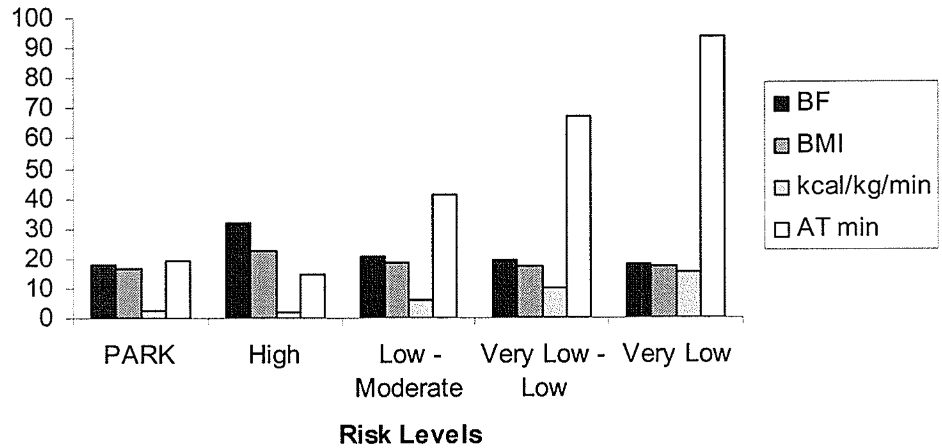

Figure 5: Risk class groups identified using K-means cluster analysis. Vertical axis represents BF (%), BMI (kg/m2), PA EE (kcal/kg/d) and AT (active time - min). X axis displays risk labels; Group 1: "PARK" - at risk due to low levels of PA, acceptable body composition measures; group 2: High risk, due to low PA and due to high body composition measures; group 3: Low to moderate risk due to PA and borderline body composition measures; group 4: very low – low risk, due to sufficient PA (EE, not active time) and ABC; group 5: very low risk, exceeding PA recommendations EE and active time, having ABC.

The PARK category, along with the dose – response relationship of increasing PA and decreasing BC can be visualized in Figure 5. Graded increases in both EE (kcal/kg/min) and active time (AT – min) correspond with decreases in both BF and BMI.

<u>Summary of Results</u>

Objective 1: The results relating to the hypothesis of objective 1 are as follows (Table 16).

a) Using objective measures of PA, less children were classified as inactive using <3 kcal/kg/d (35.9%, n = 90) than that of previously reported self report data (i.e. 57%, CFLRI, 2000 Physical Activity Monitor) (Craig 2001).
b) Using ≥ 8 kcal/kg/d, the percentage of children classified as physically active (females 13.2%, males 31.5%) was substantially less than that of self report data (females 38%, males 48%, CFLRI, 2000 Physical Activity Monitor).
c) The use of objective data provides sufficient sensitivity and specificity to identify and properly classify the 41.4% (n = 104, VLA + LA) of children who surpass the inactive EE threshold but fail to meet the active threshold.

Objective 2: Results relating to the hypotheses of objective 2 are as follows:

a) Body fat and BMI were highly correlated measures of body composition ($r = 0.83$, $p < 0.05$, Figure 1).

b) The OW and OB percentages based upon BMI in this study were similar to that of Canadian data (Table 8); 30.3% (25.4% of males and 35.0% of females) are OW and 11.0% (8.8% of males and 13.1% of females) are obese. The published BMI data on the rates of overweight and obesity in Canadian children are 33% and 26% of males and females OW and 10% and 9% of males and females OB (Tremblay, Katzmarzyk et al. 2002).

c) BMI was a less sensitive measure of body composition when compared with BF (Table 9) demonstrating the importance of using more than one body composition measure. BMI demonstrated high correlation with BF, but insufficient sensitivity to consistently detect those in the 20 – 25% BF range.

Objective 3: Results relating to the hypotheses of objective 3 are as follows:

a) Using the four risk levels (and sixteen risk classes) based upon PA and BC, 84.9% and 97.2% (Table 27) of children are at low – high risk for disease.

b) A significant inverse relationship was found between PA level and BC (Figures 3 and 4).

c) Males were significantly more active than females relative to most PA measures (Table 15). Body fat was significantly higher in females relative to males, which is contrary to our hypothesis. K – means cluster analysis demonstrated naturally occurring mathematical groupings within the data (Table 28) that paralleled the chosen risk classes for the purposes of this study, partially validating the proposed risk classification scheme.

Discussion

Currently, there is no identified study to date which relates objective measures of PA and direct BC measures in Canadian children to risk for chronic disease and sub-optimal development through the use of literature based PA and BC thresholds. This study provides a tool which can classify children for risk based upon inactivity and BC, by non-invasive methods. Further, adherence to the HC / CSEP PA guidelines for children is assessed for the first time in a large sample of Manitoban children (grades 3 – 5) through the use of objective measures.

The risk classification system applied to this sample demonstrates that 84.9% and 97.2% (Table 27) of children are at low to high risk for disease based upon a combination of physical inactivity and body composition, as measured by EE and active time respectively. Only 15.1% and 2.8% of children demonstrated "very low" risk for (relatively reduced risk or protection from) the development of chronic disease according to the risk classification schemes. The "PARK" category (those not overweight but failing to meet PA recommendations) represents 35% (Table 25) and 47% (Table 26) of the sample, when using the highest level of activity in EE and active time as "sufficient activity" respectively. This is a group that would not be identified with a classification scheme based solely upon anthropometric measures, and would likely be underestimated when PA is assessed by self report means. The classification tool used within this study uses objective measures of PA and direct BC assessment to provide a hierarchical risk scheme to classify all risk groups (including PARK) for risk for chronic disease.

K-means cluster analysis provided a useful mathematical model to confirm the risk classification scheme designed and applied within this study. K-means analysis depicted the dose response effect (Figure 5) of PA on BC (groups 2 – 5, Table 28), in agreement with the statistically significant decreases in BF (and BMI for EE) with increasing levels of activity (EE and AT). The K-means cluster analysis also identified a group that corresponds to the "PARK" category (group 1) as defined by this study; that is, children achieving insufficient activity for health benefit, but having acceptable body composition. The K-means cluster analysis provides a mathematical model that confirms the utility of the thresholds chosen within this risk classification scheme.

As hypothesized, the percentage of children classified through the use of objective measures (Table 18) as physically inactive (35.9%, < 3 kcal/kg/d) was less than that identified through self report by the 2000 Physical Activity Monitor (PAM), which reported 57% of children and youth ages 5 – 17 as inactive (Craig et al, 2001). Accelerometry assessed activity within this study classified less children as active (13.2% of females and 31.5% of males; ≥ 8 kcal/kg/d) when compared to statistics generated from self report data within the 2000 PAM; 44% of females and 53% of males. The difference between the percentages is likely due to the lower sensitivity of self reported PA. Using the Health Canada guideline of greater than or equal to 90 minutes of activity at moderate to vigorous intensity, only 4% of the sample (Table 18) would be considered meeting the endpoint of the guideline, or "active enough for health benefit". The HC / CSEP guidelines recommend all children work to increase their activity over time (a period of up to five months) to achieve the 90 minute threshold. In addition, a *reduction* of 90 minutes of inactive time is also recommended over this five month period. While this is not accounted for this study, it is of interest to note that this would in essence represent an increase in active time totaling 180 minutes per day (90 minutes increased activity at moderate and vigorous levels, and 90 minute reduction in inactive time – consequently resulting in an additional 90 minutes of active time).

Greater than half of the children (64.9%, n = 161) exceed the inactive threshold established by CFLRI of 3 kcal/kg/d (see Table 18) using energy expended from moderate and vigorous physical activity (EE). However 41.4% (n = 104) exceed the inactive threshold (< 3 kcal/kg/d) but fail to meet or exceed the active threshold (8 kcal/kg/d). Taken together with the inactive group, this represents 77.3% of children who are not meeting the EE PA guidelines. The 41.4% of children who are not inactive are still at risk for disease and suboptimal development due to insufficient PA levels. This group is not identified by the PAM using self report data. However the use of objective data and a PA risk classification system with 4 levels of categorization allows for these distinctions to be made so that interventions can be tailored to all risk groups, and change (with intervention or merely over time) can be monitored with increased sensitivity within a sample.

A relatively recent study (Pate, Freedson et al. 2002) assessed the compliance of 375 U.S. children (grades 1 – 12) to two sets of PA recommendations through the use of uniaxial accelerometry. They compared these children to two components of the Healthy People 2010 (HP 2010) recommendations; accumulation of:

i) $\geq$ 30 min, $\geq$ 5 d/wk, $\geq$ 3 METS = 150 min/week

ii) $\geq$ 20 continuous minutes, $\geq$ 3 d/wk, $\geq$ 6 METS = 60 min/week

The sample was then assessed for compliance to the United Kingdom Expert Consensus Group guidelines; accumulation of:

i) $\geq$ 60 min, $\geq$ 5 d/wk, $\geq$ 3 METS. = 300 min/week

Over 90% of their sample met the first HP 2010 objective. The majority of children (69.3%) met the United Kingdom guidelines. Both of these guidelines are based upon the accumulation of relatively low intensity of activity, and as demonstrated children easily exceed these goals in the face of the alarming rise in obesity prevalence. However when the most stringent intensity recommendation of the three was assessed (HP 2010, ii) less than 3% achieved this level of activity, despite the fact that the activity time was less than ½ to 1/5 the other recommendations in terms of duration/week.

This trend of alarming rates of non-compliance with more rigorous PA thresholds is also evident within this study. If all physical activity (AA) is counted toward achievement of HC recommendations, children on average far exceed the 8 kcal/kg/d threshold, with an average EE of 17.6 kcal/kg/d, 17.3 kcal/kg/d, 19.3 kcal/kg/d for third, fourth and fifth grade children respectively (see Table 14 "AA"). In fact a surprising 98% (n = 246) of children would be considered active (data not shown). If the same assessment was made with only activity accumulated within CB, 78.1% (n = 196) children would be considered sufficiently active. However, if only MC activity is counted toward PA classification only 22.7% (Table 18) of the sample is active. Using our most stringent recommendations of $\geq$ 90 minutes of moderate to vigorous PA, only 4.0% of children are active (Table 18). The literature supports the notion that moderate and vigorous intensity activity is necessary for health benefit (Uusi-Rasi, Haapasalo et al. 1997; Sothern, Loftin et al. 1999). In light of the current rates of OW and OB in children, and the relationship between MC PA and body composition, it is a logical conclusion that the majority of children are not sufficiently active. This is clearly demonstrated by the lack of compliance to the HC PA recommendations when only moderate continuous PA is used in the compliance assessment.

Recently, several risk classification schemes have been proposed for children based upon PA / BC and risk for cardiovascular / metabolic disease. A recent study by Katzmarzyk and colleagues (Katzmarzyk, Tremblay et al. 2003) sought to specifically define the relationship between coronary heart disease risk factors and the international OW and obesity cutoffs proposed by Cole and colleagues. This study is highly relevant for two reasons. First, it seeks to verify that the BMI guidelines (used within this study) correlate with disease risk in children. Second, the study by Katzmarzyk proposed a risk classification scheme based upon BMI that can be compared with the tool developed within the present study. Katzmarzyk et al. assessed 410 males and 337 females (9 – 18 years of age) from the Quebec Family Study, for BMI and cardiovascular risk factors (blood pressure, lipids and lipoproteins, plasma glucose and physical fitness as assessed by cycle ergometer PWC test). Values for these risk factors above the 90% percentile were considered "elevated" risk factors. Using the BMI thresholds developed by Cole and colleagues, odds ratio was performed to evaluate the relationship between OW and CV risk factors. Overweight males demonstrated 1.6 – 5.7 times the risk for elevated CV risk factors, while OW females demonstrated 1.6 – 9.1 times increased risk. Interestingly, this sample only had three OB females and one OB male, thus one would expect the difference in risk factors, and potentially the risk ratios would increase with a more representative sample (i.e. approximately 10% rate of obesity to mirror Canadian statistics).

The only identified study relating a specific EE expenditure value to risk for metabolic syndrome is one which was performed in adults (Franks, Ekelund et al. 2004). This study used objective measures of PA and bioelectric impedance to analyze BC. An EE threshold of 67.5 kJ/kgFFM/d was identified as providing reduced risk of metabolic syndrome. Within our sample, children in the highest category of PA EE achieved on average 61.2 kJ/kgFFM/d (Tables 19 and 20), while those in the highest level of PA active time achieved an average EE of 76.3 kJ/kgFFM/d. While adult thresholds can not readily be applied to our sample it is of interest to compare these values. Expression of

EE in kJ/kgFFM/d in this study will allow comparison to future studies assessing metabolic risk and EE values in children.

Brage and colleagues have produced studies classifying risk for metabolic syndrome and insulin resistance in children based upon objectively measured PA, physical fitness and BC (Brage, Wedderkopp et al. 2004; Brage, Wedderkopp et al. 2004). These studies found significant inverse relationship between PA and metabolic risk (modified by fitness level). Fasting insulin demonstrated significant inverse relationship with PA, and significant positive relationship with body weight and skin fold thickness. While PA data was not reported in a manner that would allow direct comparison to the EE thresholds used within this classification scheme, the significant relationships between specific disease risk factors, objectively measured PA and direct BC measures confirms the premise of the classification scheme.

Exploration of the significant differences in activity between sexes yielded that on average across grades boys expend 1.1 – 3.1 kcal/kg/d more energy in PA, have longer duration of CB of activity by 5.9 – 13.7 minutes. and accumulate 0.3 – 4.6 more minutes at moderate and vigorous intensities than do girls. These results are in agreement with other studies using objective measures of PA monitoring (Trost, Pate et al. 2002). Trost and colleagues examined gender differences in children grades 1 – 12 using uniaxial accelerometry, and found females to be significantly less active than males across most grades for moderate activity and across all grades for vigorous PA. Females were found to have significantly fewer 5, 10 and 20 minute bouts of both moderate and vigorous PA between the grade groupings of grades 1 – 3 and 4 – 6. Our results agree with Trost et al, in that females accumulated less time (minutes) overall in moderate and vigorous activity. However, in the present study females were in fact found to have more frequent CB of activity than males (0.5 – 1 bout / day). Interestingly, there was no difference observed in average intensity of CB between males and females. Further exploration of the data revealed that the average intensities of CB did not differ due to the fact that girls accumulate more frequent CB, spend shorter amounts of time in CB of activity and accumulate fewer minutes at moderate and vigorous intensity. Thus on average, the intensity of CB of activity would not differ between the sexes. The ability to glean this type of information from physical activity data is very important to guide intervention development. One must be able to identify differences in activity *patterns* between sexes, ages, inactive and active children to tailor interventions. Self report PA data is not sensitive enough to allow this level of detailed analysis to facilitate intervention development.

Within the template used to analyze the accelerometry data, a method to track time of day of physical activity bouts was also incorporated (Table 33, Appendix A). This could be used to provide additional insight into differences between sexes, grades and activity classes. The analysis of the time of day data however is beyond the scope of this thesis.

BMI and body fat were highly correlated measures of body composition (Figure 1); however BMI appears a tool best suited to detect the extremes of body composition. Highest sensitivity was demonstrated with BMI when relating OW and OB to higher levels of body fat (Table 9). When relatively lower percentages BF were used to define OW (20% vs. 25%) and OB (25% vs. 30%) BMI exhibited decreased sensitivity, and an increase in type II error rate when assuming that skin folds are the gold standard.

The percentage of children OW and above (BMI) within our sample is 30.3% (25.4% of males, 35.0% of females), and percentage OB is 10.9% (8.8% of males, 13.1% of females – Table 8). This is largely in agreement with the published BMI data on the rates of overweight and obesity in Canadian children (33% and 26% of males and females OW and 10% and 9% of males and females OB) with the exception that published rates of OW and OB in Canadian children identify a higher percentage of males than females as at risk due to BC, while the opposite is true within this sample.

As expected both BMI and BF increased with grade. We did not predict that females would demonstrate higher levels of body fat than males, however there was a significant sex difference in BF in this relatively large sample. BF was superior to BMI for the prediction of difference in BC between sexes. Using both BF and BMI, significant dose response differences (decreasing BF and BMI with increases in PA) were detected between body composition and PA EE classes. However, BF was superior to BMI to detect difference in body composition between PA active time classes. BMI demonstrated a similar trend (increasing BMI with decreasing active time) with active time but failed to reach statistical significance. It is important to appreciate that BMI is an indirect BC measure with low sensitivity relative to BF and other more direct BC measures. This decreased sensitivity is a limitation of BMI when assessing differences in BC between the above groups. The importance of using multiple or more direct measures of BC is highlighted by the decreased sensitivity of BMI.

This sample consists of children in grades 3 – 5 from low socioeconomic backgrounds, which must be considered when one attempts to generalize these results to other groups of individuals. However the tools used for measurement and classification purposes are valid in a wide range of ages and SE regions. As there is inconsistent data regarding the effect of physical education on daily physical activity, schools were specifically chosen to include two schools with daily physical education and two with physical education every other day to negate possible effects of physical education classes within a day. A criticism of this study could be the number of days used for accelerometry analysis per child. Studies performed since the collection of the data used for this study recommend four to seven days of accelerometry measurements on children to depict PA patterns (Trost, Pate et al. 2000). However younger children (grades one through six) show less day to day variability, and studies have demonstrated that the use of movement detectors for activity analysis in children during key periods (recess, after school) is most essential (Welk, Corbin et al. 2000). The use of multiple trials / child throughout the year helps to reduce the seasonal effect of one bout of measurement / child. Most importantly, the repeated measures analysis demonstrated no significant difference in day to day measurements in the children measured in this sample.

Thus, this study uses published literature to define risk categories based concurrently on PA and BC to assign risk level for chronic disease and sub-optimal development. Children who are classified as ABC or < 20% BF, and met or exceeded HC / CSEP PA recommendations are classified as having very low risk for chronic disease due to the protective effect and health benefits of PA and ABC. Children falling just short of the PA recommendations, and surpassing the ABC threshold are classified into the low risk for chronic disease category. Children with higher BC values (20-30% BF, OW BMI) and lower PA accumulation (3 – 6 kcal/kg/d EE, 30 – 59.9 min active time) are considered at moderate risk for disease, while the children at the highest BC values (>30% BF, OB BMI) and lowest PA levels (< 3 kcal/kg/d, 0 – 30 min active time) are classified as high risk for chronic disease. As demonstrated in the review of literature, increased BC values and insufficient PA does not only represent increased risk for chronic disease, but also places a child at risk for inadequate physical, social and psychological development. Therefore, the risk classification tool developed within this study can perform the following important functions:

i) define the current "at risk" population

ii) help tailor interventions to increase activity in all risk classes

iii) assess the specific outcomes of interventions (i.e. which class(es) of children shifted categories with intervention), and

iv) facilitate continual improvement of interventions to optimize outcomes (increased PA and improved BC) to prevent chronic disease and promoting lifelong health and wellness, beginning in childhood.

Conclusions

Objective physical activity data and two methods of body composition were assessed within this large sample of grades three to five Manitoban children to assess adherence to Canadian PA guidelines for children, and to classify risk for inactivity related chronic disease and sub-optimal development. The use of this technique of classification allows assessment of activity patterns of individual children through comparison of many physical activity parameters between sexes, grades and risk classification groups.

Body composition data of the children within this study was in agreement with that previously published for Canadian children. BMI demonstrated low sensitivity as a BC measure relative to BF. With respect to physical activity; as hypothesized, the percent of children classified as active or inactive was largely different when objective PA measures used within this study were compared with previously published self report data. Less children were considered "active enough for health benefits", less children were actually "inactive" and a large portion of children fell into a previously undefined zone between the thresholds of "active" and "inactive". Only 22.7% of children met the energy expenditure PA guidelines and 4% met the time-based recommendations.

The risk classification system proposed in this paper is a tool with multiple uses, immediately applicable to classify risk for disease in children by non-invasive means and relatively accessible measuring devices. The "PARK" category is elucidated with this tool, along with those children at risk for disease due to body composition alone, and varying combinations of inactivity and body composition. The stratification of body composition and activity afford a more descriptive tool, potentially more sensitive to changes elicited with intervention programs, allowing a child to move gradually from one category to another rather than requiring a full change in body composition and activity level to move from "at risk" to "not at risk" as within a binary risk classification system.

The report of various parameters of physical activity (energy expenditure and time active as well as frequency, intensity duration of continuous bouts) reveal differences in patterns of activity between sexes, activity classes and children of varying body composition. Males accumulate more PA than females as measured by energy expenditure and time, and participate in more minutes of moderate and vigorous intensity

PA. Females within this sample participated in shorter, more frequent bouts of physical activity. There was no difference in average intensity of continuous bouts of activity between sexes within this sample. A significant dose response effect is observed between PA and BC; with increasing physical activity corresponding to decreasing body composition values. A mathematical model applied to this data revealed naturally occurring groups within this dataset corresponding to those defined in the risk classification system, thus partially validating the classification levels.

This classification tool can be immediately applied to assess other populations in respect to activity guideline adherence and body composition. The classification of such a dramatic percentage of children at varying risk levels for chronic disease and sub-optimal development reinforces the need for primary and secondary prevention of chronic disease through increased physical activity and optimization of body composition. This tool can be used to measure risk, monitor trends and develop and assess interventions with the ultimate goal of optimizing physical activity and body composition in children to improve their health and prevent disease.

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Appendix A

Automated Activity Analysis Template Development

The raw accelerometer data is imported in to a spreadsheet where an automated template performs functions and processing of the data prior to classification. These include:

a) identification of activity intensity values (threshold detection)
b) identification of continuous activity bouts

This appendix establishes the threshold values based upon published literature to be used to identify activity levels in children in order to perform template function (a) above. The remaining half of the appendix explains the rationale for the process used to identify continuous bouts (b) of activity including the systematic evaluation of signal filtering values, threshold detection and automated start and end detection using signal differentiation. The processes described within this appendix are not only integral to this study, but represent novel techniques for the analysis of accelerometry data.

Intensity of Physical Activity in Children

The System for Observing Play and Leisure Activity in Youth (SOPLAY) (McKenzie, Marshall et al. 2000) is an assessment tool in which the evaluator periodically observes children and codes their various activities as sedentary, walking or very active. The counts in the various categories are then assigned the corresponding caloric value as described in Table 30 below. The energy expenditure values that correspond with the intensity levels have been partially validated, primarily through the concurrent validation of heart rate data (McKenzie, Sallis et al. 1991).

Table 30: Energy expenditure values used by SOPLAY, displaying activity intensity category (activity) and corresponding energy expenditure value.

Activity	Energy Expenditure (cal/kg/min)
Sedentary	51
Walking	96
Very Active	144

A review of studies using objective measures to classify activity intensity in children (Torun 1994) produced results which paralleled the values utilized in the

SOPLAY classification. Torun performed a literature review on 28 studies calculating the energy cost of children's activities (ages 1.5 to 19 years). The author only included studies deemed objective and methodologically sound. The review groups studies into categories of preschool, school age, early, mid and late adolescence. Energy expenditure of activity is expressed in the units of calorie per kilogram per minute (cal/kg/min- "small c" calories), as well as multiples of BMR. Only the school age data (7-12 years) and the cal/kg/min values reported by Torun were considered for threshold development within this study. The energy expenditure approximations are provided in Table 31.

Table 31: Energy expenditure (EE) values for children based on Torun (male and female information combined). The range of mean results from multiple studies for each category shown with the overall range from combined studies in parentheses. Shaded regions indicate activity that would classify as "moderate and above" using a threshold of 96 within the present study.

Activity	**Energy Expenditure cal/kg/min (overall range)**
Lying down	35
Sitting quietly	32-40 (30-52)
Standing quietly	40-69 (36-69)
Standing and moving	67-88
Walking free velocity, level ground	68-76 (65-77)
At school (classroom)	55-84
Walking fast/uphill/carrying a load	110 (105-118)
Leisure time, moderate play	64-103 (61-126)

The range of values for each activity descriptor provided by Torun is presented in Figure 6. A threshold of 96 cal/kg/min is denoted on the graph. Note that the activities that fall below the threshold of 96 cal/kg/min tend to be of low intensity, while those that cross the line and surpass the threshold are activities of moderate to vigorous intensity.

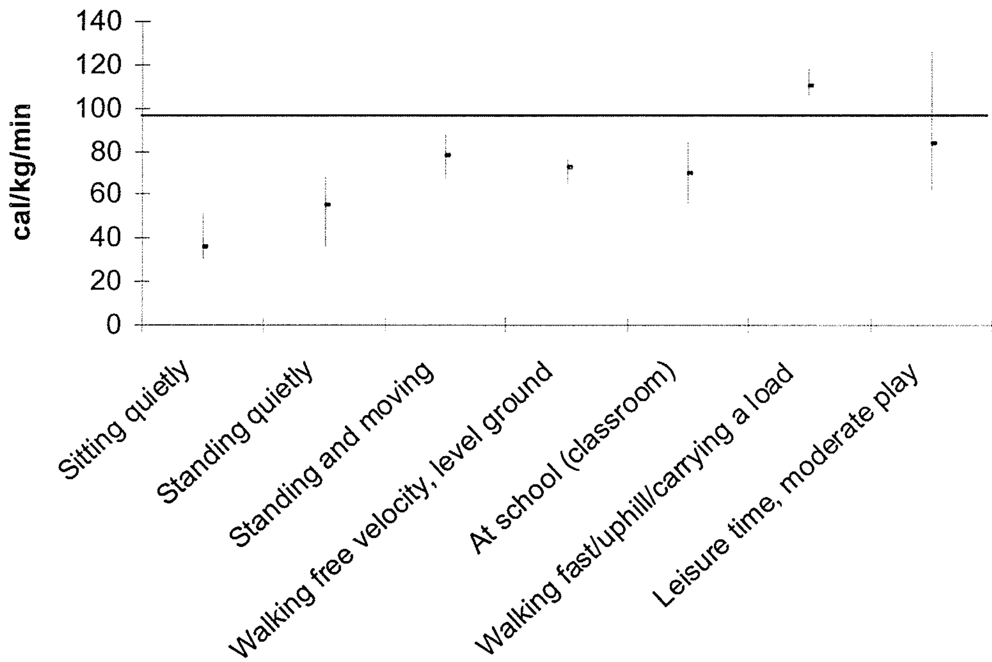

Figure 6: High-low-mean plot of intensity thresholds identified in review by Torun. Intensity threshold identified corresponding to approximately 96 cal/kg/min (moderate intensity activity). Activities of moderate to vigorous intensity cross / surpass the threshold, while those of lower intensity fall below the threshold.

By using the above references, the following intensity classification was input into the template to classify the minute-by-minute accelerometry data based upon intensity (see Table 32):

Table 32: Thresholds for analysis of raw accelerometry data, displaying activity intensity category and corresponding energy expenditure thresholds.

Intensity	Threshold (cal/kg/min)
Low	<51
Obligatory	51-95.9
Moderate	96-143.9
Vigorous	≥144

For the purposes of this study, obligatory activity is considered that which is necessarily performed through activities of daily living. For example, the low intensity activity accumulated through a child's school day walking from one classroom to another would be classified as obligatory. This activity is defined as intensity from 51 to 96 cal/kg/min, usually of short duration, and can occur independent of moderate and high intensity activity as in the previous example, or occur in conjunction with bursts of moderate and high intensity activity. An example of this would be a child who walks to school at pace that ranges between obligatory and moderate intensity. To provide a conservative approach, the template was designed to identify activity at and above the "obligatory" intensity when it was in the context of a continuous bout.

Activity Template: Continuous Bout Assessment

Most studies to date which analyze accelerometry data in relation to PA intensity will sum the total minutes above a predefined intensity threshold, to determine minutes of activity accumulated within the respective intensity. A method of detection of CB of activity has been described for use with uniaxial accelerometers (Pate, Freedson et al. 2002; Trost, Pate et al. 2002). These authors used a simple signal processing technique on accelerometry data to assess PA patterns between sex and grades and in obese and non OB children. Continuous bouts of activity of 5, 10 and 20 minutes in length were identified, with intensity $\geq$ 3 METS and repeated with a threshold of $\geq$ 6 METS. To allow for the variation of intensity that can occur in a period of activity for a child, the process used in these studies allowed intensity to drop below the threshold (3 or 6 METS) for one minute within a ten minute CB, and for two minutes within a 20 minute CB. Within a five minute CB all minutes had to surpass the intensity thresholds. These techniques allow comparison of participation in 5, 10 and 20 minute CB between sex, grade and BC. Comparison of participation in various intensity levels can also occur, through comparing CB's identified at 3 METS and 6 METS. A drawback of this technique is that only CB of activity within the defined intensity and time domains are identified. What is lacking is the ability to comment on average intensity and duration and frequency of naturally occurring CB within children. Also, while the intensity and duration thresholds appear logical, the authors do not report on systematic validation of the techniques and thresholds used.

The ability to describe naturally occurring patterns of activity within children (intensity, duration and frequency of CB) was retained within this study by the systematic validation of literature based thresholds (Torun 1994; McKenzie, Marshall et al. 2000) to identify CB within a child's day. Two functions were necessary to identify CB from raw accelerometry data;

a) averaging of the intensity profile (kcal/kg/min) to eliminate brief decrements of intensity within an CB
b) application of thresholds to denote initiation and cessation of CB

Averaging intensity to eliminate brief decrements of intensity

A physical activity profile based upon raw accelerometry data is presented in Figure 7. In the raw data, intensity is based upon the vector magnitude value produced by the accelerometer software. These profiles are useful to visually analyze activity patterns. Persisting elevation of the baseline indicate continuous sessions of activity. The same profile shown in Figure 7 is converted to cal/kg/min and shown in Figure 8. Within the accelerometry profile, one can see variations in intensity, and patterns of continuity within activity. In this profile, the baseline is consistently elevated (at 27.6 cal/kg/min) representing BMR of this individual child. Persisting elevation from BMR represents CB of activity within this profile. Visual analysis of activity patterning reveals that a child may engage in activity at a particular intensity, pause or dramatically lower the intensity of activity for a brief period (1-2 minutes) and then resume activity within one CB.

If continuous sessions of activity were merely identified by setting a defined intensity threshold (51 cal/kg/min) to the raw data, by which activity intensity has to exceed the threshold to count as initiation of a continuous bout and the bout ends as the intensity falls below the threshold, there is possibility of false classification of one bout into several bouts, and the potential for exclusion of minutes of activity just below the defined threshold. Intensity thresholds of 51, 96 and 144 are applied to the activity profile in Figure 9. Note that each of the thresholds represents missed minutes of activity within the continuous bout. Further, if initiation and cessation of the bout were respectively identified as the points at which the intensity surpassed and fell below and the threshold, each of the thresholds would overestimate the frequency and underestimate the duration of CB within a child's day.

Conversely, if the template was designed to count any elevation of the intensity above BMR as the start of a bout, and return to zero as the end, low intensity movement such as shifting of postures in sitting would be included as physical activity. Ideally then, the template should function to pick up activity which is sustained, and of sufficient average intensity to contribute to health benefit. The goal was to develop a template to identify CB which incorporates techniques and thresholds that are sensitive enough to extract true CB of activity and specific enough to exclude low activity or that not contributing to a CB.

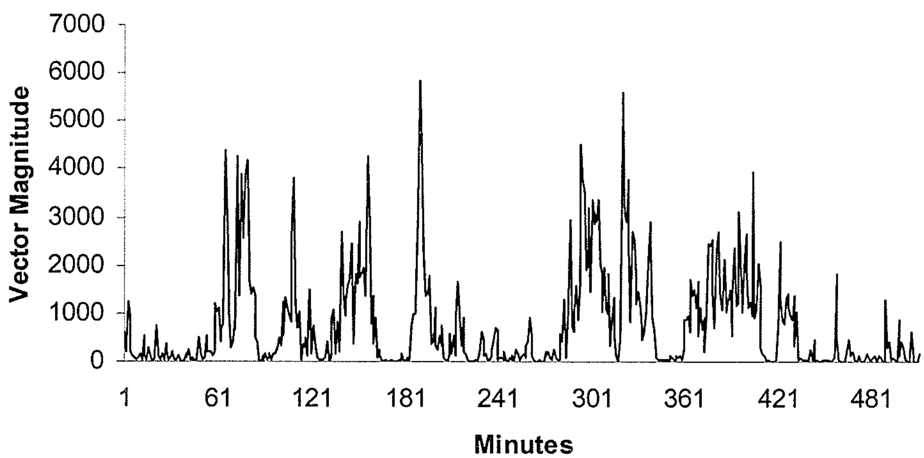

Figure 7: Accelerometer activity profile displaying minutes worn on x-axis and minute summed vector magnitude of acceleration on y-axis. Elevations of the baseline from zero represent movement as detected by the accelerometer. A higher VM value corresponds to higher intensity activity. CB of activity can be visualized when the baseline of the graph remains elevated, with a range of activity intensity occurring.

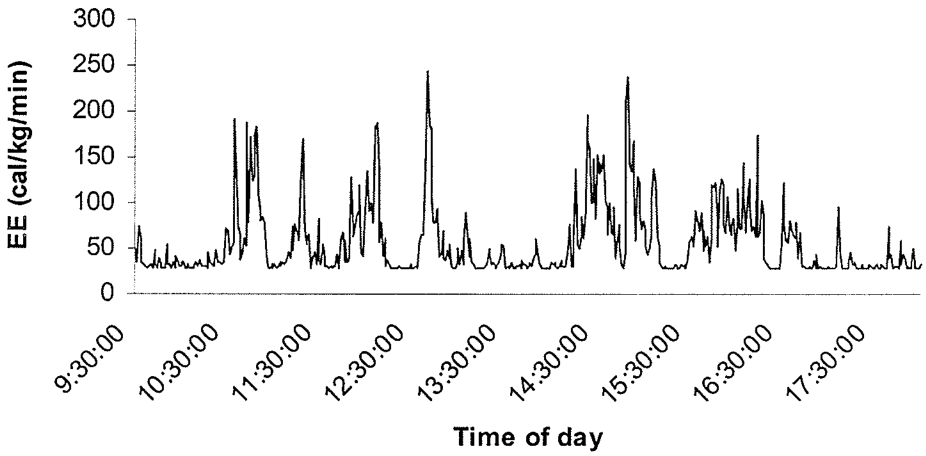

Figure 8: Accelerometer activity profile corresponding to figure 2. Minutes have been converted to time of day along the x-axis. VM has been converted to total energy expenditure (energy expenditure from PA and BMR) in cal/kg/min along the y-axis. Note the preservation of the activity pattern as represented by the relative shape of the graph. The persisting elevation of the baseline represents the inclusion of BMR (approximately 27.6 cal/kg/minute for this subject).

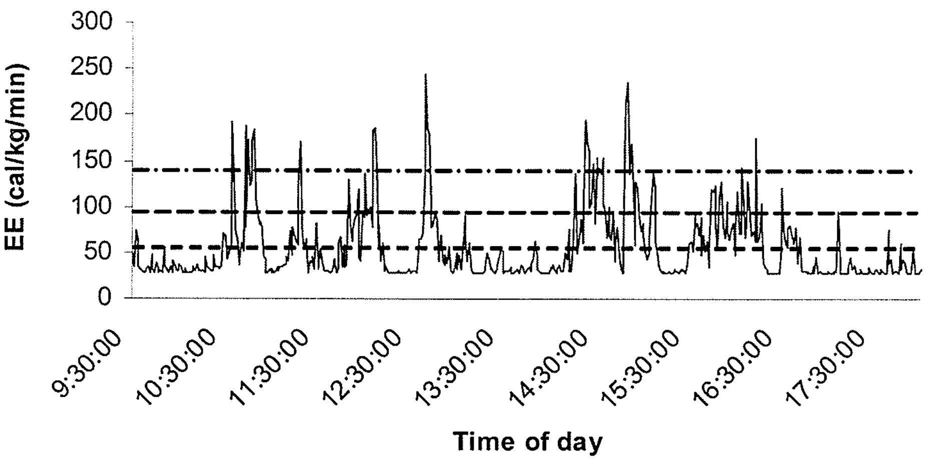

Figure 9: Accelerometer profile with intensity thresholds of 51, 96 and 144 cal/kg/min identified. Note the tendency for activity intensity to rise and fall about each threshold within the same CB.

Systematic Validation of Averaging Values and Intensity Thresholds

It was necessary to compute a moving average for the raw data to facilitate identification of periods of continuous activity while eliminating the effect of brief decrements in intensity that could occur within a CB of activity. The moving average functions as a low pass filter resulting in the inclusion of one and two minute decreases in intensity within a CB (Figure 10). Upon determination of duration over which to apply the moving average, a threshold value must be used to identify the initiation and cessation of activity. Activity exceeding this intensity threshold will trigger the "initiation" of the CB, and the minute that intensity falls below this predetermined threshold will be marked by the template as cessation of the CB.

While the goal was to include activity at and above 51 cal/kg/min ("obligatory") that contributed to CB, the actual value of 51 cal/kg/min can not be used to identify CB of activity above low intensity, because the moving average of the raw data produces altered values (reduced through a low pass filtering effect) for the minute values of energy expenditure (i.e. artificially lowering values at the initiation of a CB as intensity is just beginning to increase from a lower value).

An iterative approach was used to determine the optimal combination of averaging length (minutes) and triggering threshold (cal/kg/min). Correlation between minutes in obligatory and above intensity activity as summed from the raw data, with that identified by the template was examined. A perfect correlation was not desirable or expected as the template should selectively identify only those minutes within CB. Analysis was performed using 5 minute to 30 minute moving averages with intensity thresholds from 40 – 60 cal/kg/min. Cross-comparison and correlation was performed between the averaged and raw data. A moving average of 15 minutes was determined to retain the original data profile (i.e. length of bout) while providing the desired "smoothing" the effect of brief pauses in activity. A threshold of 48 cal/kg/min provided an acceptable correlation between raw data and that identified by the template ($r = 0.67$, Figure 11). Thus a critical automated template function was the application of the 15 minute moving average to the raw total energy expenditure data, and the use of 48 cal/kg/min to identify initiation and cessation of activity (see Figure 12). The use of 48 cal/kg/min (as opposed to 51 cal/kg/min) results in a broadened capture area, thus providing a more liberal view of a child's physical activity time. This is a recognized factor of this physical activity detection method.

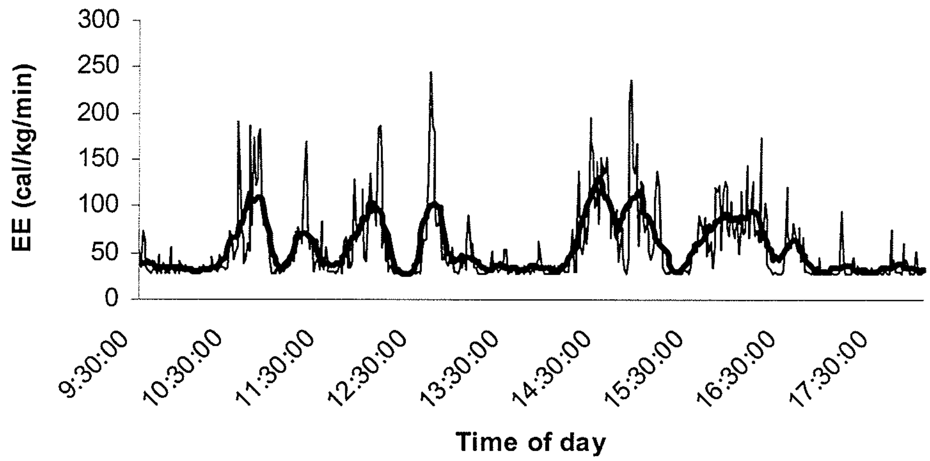

Figure 10: The 15 minute moving average (in bold) applied to the total energy expenditure data. Note the smoothing effect of brief decrements in activity, and preservation of overall pattern of activity.

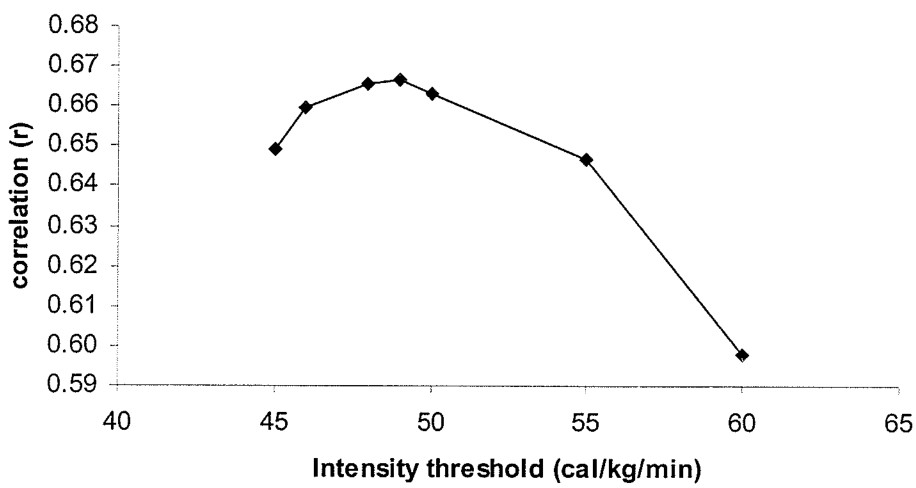

Figure 11: Tuning curve formed by iterative analysis to determine intensity threshold for detection of CB of activity. The value of 48 cal/kg/min was chosen as it lies on the ascending portion of the curve, illustrating a correlation of 0.67 between the minutes identified within continuous bouts and minutes of activity ≥ 51 cal/kg/min.

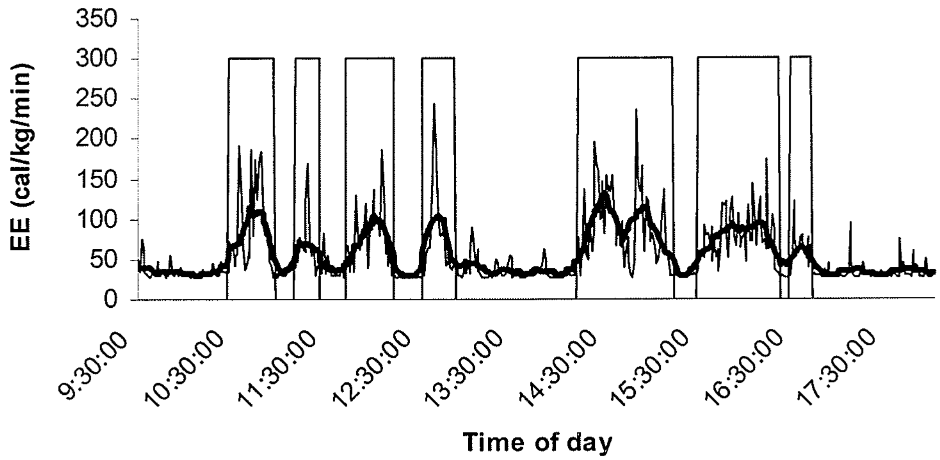

Figure 12: Identification of continuous bouts of activity (rectangular regions enclosing continuous bouts – automatically generated by the template. A CB is triggered when the averaged value for total cal/kg/min reaches 48 cal/kg/min, and ceases when the averaged value falls below 48 cal/kg/min. Seven CB of activity are identified in this activity profile by this method.

Automatic Extraction of Continuous Bouts using Differentiation

The identification of CB uses a signal differentiation method as described below (refer to Table 33). Each minute spent above 48 cal/kg/min was automatically marked (set to a value of 1); the first and last minutes of a bout of activity above threshold representing the initiation and cessation of that activity session respectively. Values below threshold were set to 0. This binary column was the "identify CB" column. Differential identification (DI) was used to extract these bouts whereby the mathematical differentiation of a series of binary numbers results in a characteristic signal which readily identifies transitions. The template automatically performed DI using the ones and zeros generated by the triggering threshold. This column was immediately adjacent to the identification column. For every cell in the "identify CB" column, it subtracted the value of the cell above, and the result was entered in the DI column adjacent to that cell. If there was no continuous activity at that time, a zero subtracted from zero would place a zero in the DI column. The minute a CB started, a one would appear in the "identify CB" column. Subtracting the zero in the cell above would place a "1" in the corresponding DI cell. As activity within that bout continued (averaged values continued to exceed 48), ones would be placed in the "identify CB" column. Subtraction of 1 from 1 would place a zero in the corresponding DI cell. Zeros would continue to be generated in the adjacent DI cell for the duration of the CB. The minute activity ceased (averaged total activity cal/kg/min value less than 48) a zero would appear in that cell of the identification column, and subtraction of 1 from that zero would automatically place a "-1" in the corresponding DI cell.

In adjacent columns to this (not shown), sums were generated based upon kcal/min values and cal/kg/min values of the CB's. If there was a "1" in the identification column, the raw caloric values (as opposed to the averaged values) were placed in their respective columns. These EE values were summed for the duration of the CB. If there was not a "1", the energy expenditure (caloric) values did not contribute to the running summation. Similarly, the consecutive 1's in the identification column were summed in a separate column. Since the raw data is recorded in one-minute intervals, this represented time in minutes spent in CB of activity. The DI column was filtered by "-1". Due to the summing of energy expenditure values in the adjacent cells, the filtration of data by the last minute of the CB provided the running total caloric expenditure achieved at that point from CB of activity. This filtered data was then copied and pasted into a separate worksheet.

Table 33: Excerpt from accelerometer template showing both raw data (first three columns) and example template functions (remaining columns). Column four and five are automated conversions of VM to energy expenditure in cal/kg/min, activity only (not including BMR) and total (activity expenditure + BMR) respectively. Column five (shaded) is the application of a 15 minute moving average applied to the total cal/kg/min column, column six replicates the time stamped data, column seven is the "identification column", using a threshold of 48 cal/kg/min applied to the 15 minute averaging data to identify CB of activity. The final column (DI) uses differential identification to tag initiation ("1") and cessation ("-1") of CB of activity. A 16 minute CB is identified in this Figure, beginning at 11:10 and ending at 11:25.

Date	Time	Vector Magnitude	activity cal/kg/ min	Total cal/kg/ min	AVG 15MIN RUNNING	Time	Identify CB	DI
03/13/2002	11:08	262.322	9.764	37.350	45.478	11:08	0	0
03/13/2002	11:09	490.342	18.252	45.837	47.485	11:09	0	0
03/13/2002	11:10	335.061	12.472	40.057	53.895	11:10	1	1
03/13/2002	11:11	1240.673	46.182	73.768	62.955	11:11	1	0
03/13/2002	11:12	555.853	20.691	48.276	65.789	11:12	1	0
03/13/2002	11:13	1321.42	49.188	76.773	67.081	11:13	1	0
03/13/2002	11:14	1134.26	42.221	69.807	68.868	11:14	1	0
03/13/2002	11:15	938.653	34.940	62.525	70.727	11:15	1	0
03/13/2002	11:16	844.504	31.435	59.021	70.174	11:16	1	0
03/13/2002	11:17	2653.25	98.764	126.349	69.876	11:17	1	0
03/13/2002	11:18	3815.533	142.029	169.614	69.779	11:18	1	0
03/13/2002	11:19	1189.884	44.292	71.877	67.925	11:19	1	0
03/13/2002	11:20	700.984	26.093	53.678	66.897	11:20	1	0
03/13/2002	11:21	879.9	32.753	60.338	67.311	11:21	1	0
03/13/2002	11:22	1022.219	38.051	65.636	65.145	11:22	1	0
03/13/2002	11:23	39.408	1.466	29.052	63.186	11:23	1	0
03/13/2002	11:24	370.331	13.785	41.370	62.914	11:24	1	0
03/13/2002	11:25	295.801	11.010	38.596	57.110	11:25	1	0
03/13/2002	11:26	493.66	18.376	45.961	47.834	11:26	0	-1
03/13/2002	11:27	141.602	5.270	32.856	45.109	11:27	0	0
03/13/2002	11:28	1488.395	55.404	82.989	43.478	11:28	0	0

Automated Individual Physical Activity Summary

Within this second worksheet, the division of energy expenditure for a CB by its duration (min) provided an average intensity for that continuous bout. Averaging of the individual CB intensity and duration values provided an overall average intensity and duration using all CB within that child's day. Number of CB per day was also tallied.

A summary of this data was linked to a final worksheet which arranged the values in a specific order and format to facilitate export into an Excel spreadsheet for analysis of the whole sample (see Table 34). To standardize data for the time that the accelerometer was worn, the units of measurement and analysis were converted to EE unit / hour and then multiplied by 16 hours to provide a generous estimate of what a child could achieve over a full day. For the purposes of relating the physical activity data from this study to HC recommendations and other literature regarding children's activity levels, energy expenditure has been calculated first in kcal/kg/d and as a secondary measure for comparison purposes, in kilojoules per kilogram of fat free mass per day. Energy expenditure units relative to a measure of body mass are recommended for comparison of activity between individuals, especially with the use of accelerometry (Ekelund, Yngve et al. 2004).

Table 34: Example of simplified summary formed by activity analysis template displaying sum of minutes (min) spent and kcal expended in moderate and vigorous (mod +) intensity activity, and overall kcal/kg/d classification for this child. Also provided: averages for CB of activity, including the total sum of kcal expended in CB over time worn (sum kcal/min), the average intensity of continuous sessions (avg c/kg/min/CB), average duration of CB (min/CB) and number of CB over time worn (# of CB).

Summary			
min mod+	Kcal mod+	kcal/kg/d	
65	260.62	9.11	
CONTINUOUS SESSIONS: GENERAL AVERAGES			
sum kcal/min	Avg c/kg/min/CB	Min/CB	# of CB
542.7052	231.1727	32.42857	7

Appendix B

Activity Analysis Template Output – Energy Expenditure and Active Time

As previously stated, PA at and above moderate intensity, and of relative continuity is promoted by the PA guidelines and the literature as necessary for health benefit. Thus, only activity of moderate and higher intensity, accumulated within CB was ultimately used to classify each child into their respective PA categories. However the template was designed to allow a thorough activity analysis, and thus provide the amount of energy expended due to physical activity of all intensities irrespective of continuity. Four final levels of "activity inclusion" were produced from each child's profile:

i) AA: all activity (> 51 cal/kg/min, regardless of continuity),

ii) AC: all continuous activity (> 51 cal/kg/min, identified within continuous bouts),

iii) AM: all moderate activity (> 96 cal/kg/min, regardless of continuity),

iv) MC: moderate continuous activity (> 96 cal/kg/min, identified within continuous bouts).

The total energy expenditure for all activity and all moderate activity (AA and AM) was determined by summing of all minutes with intensity (cal/kg/min) greater than 51 (AA) and 96 (AM). Only activity performed within CB of activity were used to compute total energy expenditure for all continuous activity (AC) and continuous moderate intensity activity (CM). All minutes within continuous bout of activity as identified by the template (which would include obligatory, moderate and vigorous intensity) were summed to provide the AC value, while CM was determined by the summation of only the minutes of moderate and vigorous intensity activity within the continuous bouts.

Activity of a moderate intensity and relative continuity is promoted by the PA guidelines and the literature as necessary for health benefit. Thus, only activity of moderate and higher intensity, accumulated within continuous bouts (CM) was used to classify each child into their respective PA (EE) categories. Expression of EE was performed relative to body mass in accordance with the literature, facilitating immediate evaluation of each child relative to the current PA recommendations. Using EE, children were categorized into one of four categories.

1. <3 kcal/kg/d (inactive, "IA")
2. 3 – 5.99 kcal/kg/d (very low active, "VLA"),
3. 6 - 8 kcal/kg/day (low active, "LA")
4. > 8 kcal/kg/d (active enough for health benefits "ACT").

These categories were based upon a combination of current PA classification schemes. The CFLRI criterion for classification of a child as sedentary (< 3 kcal/kg/d) represents IA in our sample. An "active" child as defined by CFLRI exceeds 6-8 kcal/kg/d. Currently there is not a specific classification for the children who exceed the sedentary threshold but fail to meet the minimal active threshold (6 kcal/kg/d). For the purposes of this study, these children will be classified as very low activity participants. Children exceeding CFLRI's lower "active" threshold (≥ 6 kcal/kg/d, are categorized as "LA" and those exceeding HC recommendations (and CFLRI's higher threshold) for active of ≥ 8 kcal/kg/d, are classified as "ACT".

To allow classification by active time, the template produces values representing the sum of minutes spent in moderate intensity activity, sum of minutes spent in vigorous intensity activity and a sum of these two values representing all minutes spent at and above moderate intensity activity. The summed value (minutes at or above moderate intensity activity) was used to classify the child in a secondary physical activity analysis – "active time". Four separate categories were created for active time;

i) < 30 min
ii) 30 – 59.9 min
iii) 60 – 89.9 min
iv) ≥ 90 min.