RELATIONSHIPS OF ETHNICITY, PHYSICAL ACTIVITY AND DIET WITH ADIPOSITY DEVELOPMENT IN ABORIGINAL YOUTH

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LIST OF COMMON ABBREVIATIONS

APHV – Age at Peak Height Velocity

BMI - Body Mass Index

BP – Blood Pressure

CA – Central Adiposity

CCHS – Canadian Community Health Survey

CDC – Centre for Disease Control

CPAFLA - Canadian Physical Activity, Fitness, and Lifestyle Appraisal

CVD – Cardiovascular Disease

DXA – Dual Energy X-ray Absorptiometry

FN – First Nations

GDM – Gestational Diabetes Mellitus

IOTF -International Obesity Task Force

Kcal -Kilocalories

KKD -Kilocalories per kilogram of body weight per day

MAQ-A -Modifiable Activity Questionnaire for Adolescents

MetS – Metabolic Syndrome

NCHS -National Centre for Health Statistics

NHANES -National Health and Nutrition Examination Survey

NHES -National Health Examination Survey

OB -Obesity

OW -Overweight

PA – Physical Activity

PAQ-C/A -Physical Activity Questionnaire for Children and Adolescents

PBMAS -Pediatric Bone Mineral Accrual Study

APHV – Age at Peak Height Velocity

PHV -Peak Height Velocity

SES – Socioeconomic Status

RMR – Resting Metabolic Rate

TBF – Total Body Fatness

TF- Trunk Fatness

T2D -Type II Diabetes Mellitus

WC -Waist Circumference

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1

INTRODUCTION

1.1 INTRODUCTION

Obesity is on the rise in Canada (Tremblay and Willms, 2000) and is associated with the development of cardiovascular disease (CVD), the metabolic syndrome (MetS) and type 2 diabetes (T2D) (Grundy et al. 1999; Sellers et al. 2008). In comparison to other ethnic groups, the prevalence of obesity, the MetS and T2D is disproportionately high in Canadian Aboriginal populations, including youth (Dean 1998; Health Canada 2005; Katzmarzyk 2008; Shields 2005; Young et al. 2000). While the exact reasons are unknown, it is thought that this increased vulnerability may exist due to an underlying genetic susceptibility expressed in the context of a westernized environment (Anand et al. 2001; Hegele 2001) and/or the development of a thrifty metabolism which may be an adaptation to past periods of feast and famine (Neel 1962).

Whatever the reason(s) for the higher prevalence, experts agree that the prevention of overweight and obesity, particularly in Aboriginal youth, is critical. Obesity has been shown to track from childhood into adulthood (Guo et al. 2000; 2002). Furthermore, obesity and the components of the MetS (i.e., increased waist circumference, elevated blood pressure, decreased high density lipoprotein (HDL) cholesterols, raised blood sugar levels and increased triglyceride levels (Adult Treatment Panel III 2002)) are important determinants of T2D (Canadian Paediatric Society 2005), which is on the rise in Canadian Aboriginal children (Dean 1998; Harris et al. 1996).

Although obesity and adiposity are thought to be related to increased intake of energy dense food and decreased physical activity (Tremblay and Willms, 2000), studies exploring relationships of physical activity, diet and adiposity are lacking, particularly in Aboriginal youth. While recent reports have improved our understanding of the physical activity and eating behaviors of Aboriginal Canadians (Bryan et al. 2006; Garriguet 2008; Young and Katzmarzyk 2007), this paucity of data is incongruent with the relatively large volume of information on the health status and health determinants of the Aboriginal population (Young and Katzmarzyk 2007). Given that physical activity and healthy eating may play a powerful role in enhancing the health of youth at high risk for the premature development of chronic diseases, a need exists to better understand these behaviors and clarify relationships of physical activity, diet and adiposity development in the Aboriginal population. This type of research could also lead to longitudinal studies identifying the determinants of physical activity and healthy eating in Aboriginal youth to tailor culturally appropriate interventions.

In addition to the above limitations, the majority of obesity research with Aboriginal youth has relied solely on body mass index, which does not necessarily provide an indication of central adiposity and therefore may underestimate health risk. Furthermore, few studies of adiposity in youth have controlled for biological maturity, which has been demonstrated to exhibit growth and maturation associated variation in the physical activity behaviors of boys and girls (Sherar et al. 2007; Thompson et al. 2003). Moreover, without controlling for biological maturity, it is difficult to conclude that adiposity and overweight in youth is not associated in part, with normal growth and development. These gaps in the literature limit our understanding of adiposity development and increasing rates of obesity and T2D among Canadian Aboriginal youth. A more comprehensive approach assessing total and central adiposity in relationship to ethnicity, diet and physical activity, while controlling for biological maturity, would be beneficial.

The objective of this thesis was to study the relationship(s) of ethnicity, physical activity and diet with adiposity development in Aboriginal youth. To meet this objective, three separate studies were undertaken: 1) to comprehensively assess adiposity in Aboriginal youth and their age, sex and maturity matched Caucasian peers; 2) to assess the role of ethnicity and sex on physical activity (PA) levels and identify the proportion of Aboriginal youth meeting international PA and T.V. recommendations; and 3) to explore relationships of physical activity and diet with adiposity in Aboriginal youth.

2

REVIEW OF LITERATURE

2.1 OVERVIEW

The purpose of this chapter is to provide an extensive literature review regarding adiposity, overweight and obesity in Canadian youth. It begins with an overview of overweight and obesity and associated behavioral and biological factors in the general population, and leads into a more specific discussion pertaining to Aboriginal children and adolescents. Given that adiposity, overweight and obesity are related to metabolic health problems and have become common among Aboriginal populations over the past several decades (Dean 1998; Health Canada 2005; Katzmarzyk 2008; Shields 2005; Young et al. 2000), MetS and T2D have also been referred to in this thesis.

It is important to note that this review of literature includes studies related to different Aboriginal groups within Canada, as well as Aboriginal/Indigenous groups from Australia, New Zealand and the United States. Although differences in nationality, linguistics, and ethnic and cultural traditions exist between the various Aboriginal groups within these countries, there are some similarities which make it possible to include these studies as relevant background literature. Like many other Indigenous cultures, culture, language and tradition are key aspects of a holistic view of health among Aboriginal Canadians (Raine 2004). Furthermore, many Indigenous cultures view health and well-being as an inter-relationship between physical, mental/intellectual, spiritual and emotional factors (Raine 2004). The history of colonization and its impact on the lives and health of Indigenous peoples is also common globally. Many Indigenous communities, such as the Aborigines of Australia, the Maoris of New Zealand and the native peoples of North America, live in social and political conditions that are responsible for extreme levels of poverty, poor educational opportunities, poor housing and chronic ill health (Burger 1987). While Canada, the United States, Australia and New Zealand have some of the highest standards of living in the world, the Indigenous peoples in these countries are often as poor as the most disadvantaged in Third World Countries, and their health status is often reported to be below average (Burger 1987). An additional similarity relevant to this thesis is the high rates of T2D among the Native Americans, the Aborigines of Australia and the Maori of New Zealand, which mirrors that of many Aboriginal groups in Canada. Therefore, despite the apparent diversity between the Aboriginal groups referenced in this thesis, the similarities between health disparities, health status, marginalization and socioeconomic disadvantages provide the rationale for the use of literature which extends beyond Canada.

The terms* defined below have been referred to in the forthcoming thesis:

- *Indigenous* means “native to the area.” In this sense, Aboriginal Peoples are indigenous to North America.
- *Indigenous Peoples* is an all-encompassing term that includes the Aboriginal or First Peoples of Canada as well as other countries. For example, *Indigenous Peoples* refers to the Inuit in Canada, Maori in New Zealand, and Aborigines in Australia and is generally used in an international context. As a proper name for a people, the term *Indigenous Peoples* is capitalized.
- *Aboriginal Peoples* is a collective name for all original inhabitants of Canada and their descendents. The *Constitution Act* of 1982 specifies that the Aboriginal Peoples in Canada consist of three groups: Indians, Métis and Inuit. These are three separate peoples with unique heritages, languages, cultural practices and spiritual beliefs.
- *Aboriginal people* (with a lower case people) refers to more than one Aboriginal person rather than the collective group.
- *Aboriginal* collectively refers to the descendants of the original inhabitants of North America including First Nations, Métis, and Inuit.
- *First Nation(s)* is the term which came into common usage in the 1970s to replace the name, “band” or “Indian”, which some found offensive. Although used widely today, there is no legal definition for this term in Canada. The term should not be used as a synonym for Aboriginal Peoples because it doesn’t include Inuit or Métis.
- *Métis* is French for “mixed blood.” The *Constitution Act* of 1982 recognizes Métis as one of the three Aboriginal Peoples. Historically, the term Métis applied to the children of French fur traders and Cree women in the Prairies, of English and Scottish traders and Dene women in the north, and Inuit and British in Newfoundland and Labrador. In this paper, the term is used broadly to describe people of mixed First Nation and European ancestry who identify themselves as Métis as distinct from First Nations, Inuit or non-Aboriginal people. Métis organizations in Canada have differing criteria about who qualifies as a Métis person and the use of the accent also varies by organization. The Métis have a unique culture that draws on their diverse ancestral origins, such as Scottish, French, Ojibwa and Cree.

- *Inuit* are the Aboriginal People of Arctic Canada. Inuit live primarily in the Northwest Territories, Nunavut and northern parts of Quebec and throughout most of Labrador.
- A *band* is a community of Indians for whom lands have been set apart and for whom the Crown holds money. It is a body of Indians declared by the Governor-in-Council to be a band for the purposes of the *Indian Act*. Many bands today prefer to be called First Nations and have changed their names to incorporate First Nation (e.g., the Batchewana Band is now called the Batchewana First Nation).
- A *tribe* is a group of Native Americans sharing a common language and culture. The term is used frequently in the Unites States, but only in a few areas of Canada (e.g., the Blood Tribe in Alberta). In this thesis, the term *tribal group* refers to the unique culture that draws upon the diverse ancestral and origins of the self-identified First Nations youth in this study (e.g., Cree, Ojibway, Dene, etc.).
- A *reserve* is land that is set aside by the Crown for the use and benefit of a First Nations band in Canada. Many First Nations now prefer the name, *First Nation Community*, rather than the term *reserve*. Note that this term is capitalized only when used as part of a name, otherwise it should remain lowercase.
- *Off reserve* is the term used to describe people, services or objects that are not part of a reserve, but relate to First Nations.

*Adapted from the National Aboriginal Health Organization (NAHO) Terminology Guide, 2003; and Indian and Northern Affairs Canada (INAC), 2003.

2.2 OVERWEIGHT AND OBESITY IN CANADA

Obesity, a condition characterized by excess adiposity to the extent that it may compromise health, is increasing in both developed and developing countries so rapidly that it has been described as a global epidemic (World Health Organization 2000). Over the past few decades, obesity has become a major metabolic and nutritional concern (Kiess and Boettner 2002), surpassing malnutrition and infectious disease as the most significant contributor to morbidity and mortality (Lau et al. 2007). The high prevalence and incidence of overweight and obesity represents a public health concern that shows few signs of improving in the near future.

The terms overweight and obesity are often used interchangeably, but are not synonymous. Overweight is characterized by a moderate degree of excess weight for height, while obesity is more severe. Although a variety of methods have been used to assess and define overweight and obesity, data show consistent trends of rapidly increasing rates, particularly among children (Ball and McCargar 2003; Shields 2005; Tremblay and Willms 2000). Although the majority of research at the population level has relied on self-report, measured heights and weights from two national data sets (i.e., the 1978/79 Canada Health Survey and the 2004 Canadian Community Health Survey) were compared to indicate the change in rates of overweight and obesity for youth over a quarter century (Shields 2005). Results showed in 1978-79, 12% of Canadian children and adolescents (2-17 years) were considered overweight and 3% were obese; a combined overweight/obese prevalence of 15% (Health and Welfare Statistics Canada 1981). By 2004, 18% of Canadian youth (2-17 years) were considered overweight and 8% were obese; a combined prevalence of 26% (Shields 2005). Although this same study showed increases in overweight and obesity were similar between boys and girls, trends emerged with different age groups. For example, in preschool children (aged 2 – 5 years), there were no significant changes in the overweight/obesity prevalence, but in other age groups, overweight/obesity rates doubled, from 13% to 26% for children (6 to 11 years) and from 14% to 29% for adolescents (12 to 17 years), in the same time period. Additionally, in adolescents, the obesity rate alone tripled, from 3% to 9% (Shields 2005). Thus, this data indicates that over a span of 25 years, more Canadian youth (6-17 years) have become overweight, and overweight youth have been progressively become obese.

The secular trends in Canadian childhood overweight and obesity are similar to the United States, and highlight a growing global trend which seems to indicate that obesity among youth is advancing at a pace more rapidly than among adults (WHO 2000). Along with risk factors for cardiovascular disease (CVD) and T2D, obesity related metabolic disorders are now being seen in children at a much earlier age and continue to progress into adulthood (Ball and McCargar 2003). Given evidence to suggest that obese children will remain obese as adults (Guo et al. 2000; 2002), the likelihood that youth today will experience premature weight related morbidity and mortality has increased substantially. Moreover, it is expected that the prevalence of obesity in adults will also continue to rise as the current generation of children enters into adulthood (Lau et al 2007).

Evidence suggests that body weight varies by ethnic origin (Tremblay et al. 2005; Willows 2005), with minority populations at highest risk for obesity (Eisenmann et al. 2003; Katzmarzyk and Malina, 1998; Kimm et al. 2002; Lear et al. 2002). In Canada, overweight and obesity have generally increased in both adults and children, but the most dramatic rise has been in individuals of Aboriginal ethnicity (see section 2.3) (Tjekema 2005; Tremblay et al. 2005). The Canadian Community Health Survey (CCHS), for example, showed that Aboriginal adults (aged 20-64 years) had the highest prevalence of self-reported obesity among all ethnic groups in Canada (Tremblay et al. 2005; Young et al. 2002). Similarly, obesity rates among Aboriginal groups are higher in the United States (Story et al. 1999), Australia (Department of Health and Ageing 2006) and New Zealand (Ministry of Social Development 2006) in comparison to other ethnic groups.

The Aboriginal population represents approximately 3.4% of the total population in Canada and its annual growth (i.e., 1.8%) is expected to more than double the rate projected for the entire population over the next few years (Health Canada 2005). A report by the Heart and Stroke Foundation (2002/03) indicated the proportion of the Aboriginal population in Saskatchewan was expected to rise from 13.5% (at the time of the study) to 33% by 2045. Recent census data (2006) showed that a growing number of Aboriginal people live in urban settings (Statistics Canada 2008) and that Saskatoon, Saskatchewan had the highest concentration of Aboriginal people in Canada (Statistics Canada 2008). Furthermore, findings showed that in Saskatoon, 50% of the Aboriginal population is younger than twenty-four (Statistics Canada 2008). These statistics suggest that the

Aboriginal population is concentrated in younger age groups and underscore the need to prevent obesity in this ethnic group, so that obesity, MetS and T2D will not be perpetuated within Aboriginal youth.

2.3 OVERWEIGHT, OBESITY AND ADIPOSITY IN ABORIGINAL YOUTH

Traditionally, Aboriginal peoples did not have high rates of obesity. However, with increasing 'westernization' and resulting lifestyle and environmental changes, overweight and obesity have risen dramatically and are significantly higher in the Aboriginal versus non-Aboriginal population. Canadian reports have indicated that the prevalence of obesity among Aboriginal children and adults (off-reserve) is approximately double that of the general Canadian population (Shields 2005; Tjepkema 2006) and that Aboriginal youth are nearly 2.5 times as likely as non-Aboriginal youth to be obese after controlling for a number of covariates (Katzmarzyk 2008). Similarly, the 2004 Canadian Community Health Survey (CCHS) (which did not include the three Territories, Indian reserves and some remote areas) showed a combined overweight/obesity rate of 41% and an obesity rate of 20% for off-reserve Aboriginal youth using measured heights and weights; the latter representing a rate 2.5 times the national average (Shields 2005). In 2008, Katzmarzyk investigated ethnic differences in obesity among a representative population sample of Aboriginal and non-Aboriginal Canadian children and adolescents (2-17yrs) (2004 CCHS data, Cycle 2.2: Nutrition) and also reported obesity rates among Aboriginal youth (15.8%) nearly twice that of non-Aboriginal youth (8.0%). Data from a community based, cross-sectional comparison study with a relatively small sample of youth of the Anishnabai Temagami of Ontario showed that obesity rates among First Nations youth (5 – 19 years) were twice that of their European counterparts living in a nearby town (Katzmaryzk and Malina 1998). Few other community studies to date have assessed adiposity development in Aboriginal youth relative to their non-Aboriginal peers using a minimum assessment of measured height and weight.

In 2006, the 2002/03 First Nations Regional Longitudinal Health Survey (RLHS), a First Nations initiative led by First Nations people, collected data from 6657 children (aged 3-11 years) in 238 First Nations Reserves across Canada (Seto et al. 2006). Findings showed over half of First Nations children were overweight or obese, and compared to younger children (3-5 years), older children (9-11 years) were twice as likely to be overweight

(28.8% vs. 13.1%) but less likely to be obese (26.4% vs. 48.7%) (Seto et al. 2006). However, estimates from this large study were based on parent/guardian report and therefore may be inflated.

Small, community-specific studies of adiposity among Aboriginal youth living on the reserve (Hanley et al. 2000; Horn et al. 2001; Young et al. 2000) generally suggest rates of overweight and obesity are as high as or higher than those reported from Aboriginal youth off-reserve. A study conducted with Oji-Cree from northern Ontario, for example, found high rates of overweight (i.e., BMI exceeding the 85th percentile for age and sex specific reference data from NHANES III) in both boys (27.7%) and girls (33.7%) (Hanley et al. 2000). Using the same NHANES reference standards, a Manitoba study with Oji-Cree living in a remote community indicated that 64% of girls and 60% of boys (aged 4 to 19) were overweight (i.e., a combined overweight/obesity rate) (Young et al. 2000). Excessive pediatric overweight (i.e., over one third of the sample had a BMI greater than the 90th percentile for age) has also been reported in James Bay Cree (girls and boys) of Quebec (Bernard et al. 1995; Ngnie Teta 2002) and in the Mohawk community of Kahnawake (Horn et al. 2001; Potvin et al. 1999; Trifonopoulos 1995). More recent research using international reference standards (Cole et al. 2000) found 33% of Cree youth (aged 9-12 years) from Quebec were overweight and 38% were obese (Ng et al. 2006). Additionally, this same study showed the mean sum of five skinfolds in the Cree youth exceeded the 95th percentile (Ng et al. 2006). Studies investigating adiposity and obesity in Aboriginal youth in Canada have been summarized in Table 1.

Table 1. Studies investigating adiposity and obesity of Canadian Aboriginal youth*

Population/Study	Age/ N	Methods	Overweight (%)	Obese (%)
Canadian Aboriginal youth (off-reserve) compared to non-Aboriginal youth 2004 Canadian Community Health Survey[i]	2-17 yrs N = 8661 (total sample)	BMI (measured) IOTF reference	21 (Aboriginal) 18 (non-Aboriginal) Defined as ≥90th to 96th percentile	20 (Aboriginal) 8 (non-Aboriginal) Defined as ≥97th percentile
Anishnabai Temagami First Nations (FN) compared to European ancestry (EA) youth from Ontario[ii]	5-19 yrs N =167; 21 (FN) + 72 (EA) males; 17 (FN) + 57 (EA) females	BMI (measured), 6 skinfolds NHANES II reference	Not reported	28.6 (FN boys), 29.4 (FN girls) 20.8 (EA boys), 12.3 (EA girls) *Defined as ≥85th percentile
First Nations (238 reserves) 2002/03 First Nations Regional Longitudinal Health Survey[iii]	9-11 years (N = 6657 total; 3-11 yrs)	BMI (parent/guardian-reports), IOTF reference	28.8 (boys & girls combined) Defined as ≥90th to 96th percentile	26.4 (boys & girls combined) Defined as ≥97th percentile
Oji-Cree in Sandy Lake, Northern Ontario[iv]	2-19 yrs N = 445	BMI (measured) NHANES III reference	27.7 (boys), 33.7 (girls) Defined as ≥85th percentile	Not reported
Oji-Cree, Manitoba[v]	4-19 yrs N = 719	BMI (measured) NHANES III reference	Overweight not reported; obesity was separated into two categories, defined as ≥85th percentile and ≥95th percentile	60 (boys), 64 (girls) Defined as ≥85th percentile 34 (boys), 40 (girls) Defined as ≥95th percentile
Cree in Northern Quebec (two Cree communities in James Bay)[vi]	9–15 yrs gr. 4/5 & 8/9 N = 144	BMI (measured) NHANES II reference	38 (boys & girls combined) Defined as ≥85th to 94th percentile	9 (boys), 24 (girls) Defined as ≥95th percentile
Cree in Northern Quebec[vii]	9-12 yrs N = 105	BMI (measured) IOTF reference WC (measured), 3 skinfolds, NHANES III reference	33 with BMI (boys & girls combined) 62 with WC 51 with skinfolds Defined as ≥90th percentile for BMI; ≥95th for WC; ≥85th for skinfolds	38 (boys & girls combined) Defined as ≥97th percentile for BMI
Mohawk of Kahnawake, Quebec[viii]	6-9 yrs N = 198	BMI (measured), WC (measured), 2 skinfolds NHANES III reference	29.5 (boys), 32.8 (girls) Defined as ≥85th percentile	Not reported
Canadian Aboriginal youth (off-reserve) compared to non-Aboriginal youth Canadian Community Health Survey 2.2 Nutrition[ix]	2-17 yrs N = 8024	BMI (measured) IOTF reference	Not reported	15.8 (Aboriginal); 8.0 (non-Aboriginal) Defined as ≥97th percentile
Cree in Northern Quebec[x]	9-12 yrs N = 105	BMI (measured) CDC reference WC (measured) NHANES III reference	23.6 Defined as ≥85th to 94th percentile 52.2 had CA (WC ≥85th percentile)	43.8 Defined as ≥95th percentile

*Note: reference standards for defining overweight and obesity in the above studies may differ, and therefore direct comparison of the prevalence rates of overweight and obesity should be made with caution.

Legend: IOTF - International Obesity Task Force; NHANES – National Health and Nutrition Examination Survey; CDC – Centre for Disease Control

i. Shields M. (2005). Measured Obesity. Overweight Canadian children and adolescents. *Nutrition: Findings from the Canadian Community Health Survey. Issue No. 1., Statistics Canada - Cat. no. 82-620-MWE*, 1-34.

ii. Katzmarzyk P.T. and Malina R.M. (1998). Obesity and Relative Subcutaneous Fat Distribution Among Canadians of First Nation and European Ancestry. *International Journal of Obesity and Related Metabolic Disorders,* 22, 1127-1131

iii. Seto and associates (2006). First Nations Regional Longitudinal Health Survey (RHS) 2002/03: Results for Adults, Youth and Children Living in First Nations Communities. First Nations Information Governance Committee, Assembly of First Nations, First Nations Centre at the National Aboriginal Health Organization. Ottawa. November 2005. Available: http: //www.naho.ca/firstnations/English/regional_ health.php. Accessed September 02, 2006. Information was based on reports from parents from selected First Nations reserves across Canada and Inuit communities in Labrador. It did not include children from Alberta, the territories, or some areas of Quebec (James Bay Cree, Nunavik Inuit and Mohawk communities).

iv. Hanley A.J. et al. (2000). Overweight Among Children and Adolescents in a Native Canadian Community: Prevalence and Associated Factors. *American Journal of Clinical Nutrition,* 71, 693-700

v. Young T.K. et al. (2000). Childhood obesity in a population at high risk for type 2 diabetes. *The Journal of Pediatrics, 136,* 365-369

vi. Bernard L. et al. (1995). Overweight in Cree Schoolchildren and Adolescents Associated with Diet, Low Physical Activity, and High Television Viewing. *Journal of the American Dietetic Association,* 95, 800-802.

vii. Ng C. et al. (2006). Obesity, Adiposity, Physical Fitness and Activity levels in Cree Children. *International Journal of Circumpolar Health,* 65, 322-330

viii. Trifonopoulos M. Anthropometry and Diet of Mohawk Schoolchildren in Kahnawake, Master's Thesis (Montreal: McGill University, 1995). Horn O.K. et al. (2001). Correlates and Predictors of Adiposity among Mohawk Children. *Preventive Medicine*, 33, 274 - 281. Potvin L, Desrosiers S, Trifonopoulos M, Leduc M, Rivard M, Macaulay AC, et al. (1999). Anthropometric characteristics of Mohawk children aged 6 to 11 years: A population perspective. *Journal of the American Dietetic Association*, 99, 955 - 61.

ix. Katzmarzyk P. (2008). Obesity and Physical Activity Among Aboriginal Canadians (2008). *Obesity,* 16, 184-190.

x. Downs S. M., Marshall, D., Ng, C., & Willows, N. D. (2008). Central adiposity and associated lifestyle factors in Cree children. *Applied Physiology, Nutrition and Metabolism,* 33, 476-482.

While many studies have reported BMI to assess overweight and obesity among Aboriginal youth, there is growing evidence to suggest that measures of central adiposity, such as waist circumference (WC), can be superior to BMI for predicting health risk (Janssen et al. 2005; Yusuf et al. 2005). A study that assessed body weight and WC for example, showed children with excess body weight and a high WC were twice as likely to have high triglycerides, high insulin levels and metabolic syndrome (MetS) compared to children with excess weight and a low WC (Janssen et al. 2005). Similarly, in a cohort of Aboriginal Australian youth, WC helped identify youth at high risk for MetS despite low rates of overweight and obesity (Sellers et al. 2008). Recent Canadian research using CDC growth charts in addition to NHANES III waist circumference percentiles in Cree youth showed 23.6% were considered overweight and 43.3% were considered obese, and 35.7% of OW youth and 97.4% of OB youth had waist circumferences greater than or equal to the 85^{th} NHANES III reference (i.e., central adiposity) (Downs et al. 2008). If these data are representative of other Aboriginal youth, using WC in combination with other measures would be worthwhile to assess central adiposity and associated health risk.

2.4 THE CONSEQUENCES OF OBESITY

2.4.1 Health consequences of childhood obesity

Obesity has been associated with several conditions and diseases (Freedman et al. 1999; Smith and Rinderknecht 2003) which have immediate risks as well as severe, lifelong effects (Daniels 2006; Schwimmer 2003). While many obesity-related health disorders and diseases (such as hypertension and MetS) were once thought of as being exclusive to adults, they are now seen with increasing frequency in children (Daniels 2006; Dean 1998; Dean and Sellars 2003) (see Table 2). Furthermore, even if an obesity-related health disorder does not present until adulthood, the symptoms and conditions related to that health disorder may appear earlier if that adult had excess body fat in childhood (Daniels 2006).

Table 2. Disorders Related to Childhood Obesity*

System and disorder	Description
Cardiovascular	
Hypertension	Persistently high arterial blood pressure
Left ventricle hypertrophy	Increased thickness of the heart's main pumping chamber
Atherosclerosis	Hardening of the arteries
Metabolic	
Insulin resistance	The process in which the action of insulin is retarded
Dyslipidemia	Abnormal changes in cholesterol and triglycerides
Metabolic syndrome (MetS)	A collection of risk factors including a minimum of three of increased WC, elevated BP, increased triglycerides and decreased cholesterol concentrations, and raised plasma glucose
Type 2 diabetes	A condition in which the body either makes too little insulin or cannot properly use the insulin it makes, leading to elevated blood glucose
Pulmonary	
Asthma	A chronic inflammatory pulmonary disorder characterized by reversible obstruction of the airways
Obstructive sleep apnea	A breathing disorder characterized by interruption of breathing during sleep
Nonalcoholic fatty liver disease	Fatty inflammation of the liver linked to high levels of blood glucose rather than excessive alcohol use
Gastroesophageal reflux	Backward flow of stomach contents into the esophagus
Skeletal	
Tibia Vara (Blount disease)	Medial angulation of the tibia resulting in bowing of the leg, due to a growth disturbance of the medial aspect of the proximal tibial epiphysis
Slipped capital femoral epiphysis	A disorder of the hip's growth plate
Psychosocial	
Depression	A mental disorder characterized by a morbid sadness and loss of interest in otherwise satisfying activities

*Adapted from Daniels (2006). Note the above table lists only more common disorders related to childhood obesity.

A key risk factor for many chronic diseases, obesity frequently co-exists with other metabolic and cardiovascular disorders (Table 2). The complex endocrine and metabolic changes of obesity typically results in increased insulin levels, which can help regulate blood sugars, but also create physiological problems, such as insulin resistance, even in young children (Daniels 2006; Dean and Sellars 2002). Insulin resistance, in turn, can result in hyperinsulinemia, dyslipidemia, hypertension, steatohepatitis, glucose intolerance, acanthosis nigricans and ovarian hyperandrogenemia (Dean et al. 2002; Klein et al. 2004; McGavock et al. 2007). The 'Metabolic Syndrome' (MetS) is defined as a collection of risk factors including a minimum three of the following: 1) elevated blood pressure; 2) increased triglyceride levels; 3) decreased high density lipoprotein (HDL) cholesterols; 4) raised blood sugar levels; and 5) increased waist circumference (Adult Treatment Panel III 2002). While the definition of the MetS varies, Cook and colleagues (2003) used an adult definition adapted for youth and found that 30% of obese children and adolescents had MetS, compared to 4% of the rest of a random sample. Similarly, Weiss and associates (2004) reported that each half-unit increase in BMI z-score (i.e., approximately half of one standard deviation in BMI) among overweight children and adolescents resulted in an approximately a 50% increase in the risk for MetS. Research has also linked overweight and adiposity to each of the independent risk factors which define MetS, such as high blood pressure (Torrance et al. 2007). For example, the likelihood of high blood pressure was significantly greater in youth with a BMI at or above the 90^{th} percentile compared to youth with a BMI at or below the 10^{th} percentile, and the risk of elevated blood pressure in obese youth was approximately 2.5 to 4 times that of overweight youth, depending on ethnicity and sex (Rosner et al. 2000). Increased triglycerides, reduced high density lipoprotein cholesterols (HDLs) and cholesterol abnormalities have also been associated with greater adiposity; atherogenic dyslipidemia, which involves abnormal changes in blood cholesterol and triglycerides (Daniels 2006), seems to be a catalyst for atherosclerosis in adults as well as children (Adult Treatment Panel III 2002). Insulin sensitivity, the term used to refer to when pancreatic beta cells compensate for insulin resistance by making more insulin but cannot keep up with its production, frequently leads to the development and progression of T2D. Findings from the Bogalusa study suggested that overweight children may be at nearly two and a half times greater risk of developing T2D by age 30 compared to their non-overweight counterparts (Srinivasan et al.1996). Insulin resistance and T2D have similarly become increasingly common in young children (Dean 1998) but will be discussed later in this literature review.

A major risk factor for the MetS, central adiposity is used to describe an accumulation of both subcutaneous and visceral adipose in the central region between the diaphragm and the hips and contains major organs, such as the stomach, liver, and intestines (Ball and McCargar 2003; Grundy et al. 2005). While central adiposity is strongly correlated with total adiposity (Garnett et al. 2005; Goran et al. 1997), findings suggest that even at a relatively normal body weight, increased central adiposity is associated with higher risk for the MetS. In 2001, Anand and colleagues showed that Aboriginal people suffer from a disproportionately high prevalence of abdominal obesity, which is strongly associated with the development of T2D, dyslipidemia and CVD. Data from urban Aboriginal youth have similarly shown that a high WC (i.e., a predictor of central adiposity) coupled with large skinfolds was associated with increased total adiposity, elevated blood pressure and increased CVD risk (Smith and Rinderknecht 2003).

In addition to the metabolic abnormalities discussed above, increased adiposity during childhood has been associated with increased risk for CVD in adulthood (Baker et al. 2007). Two risk factors for CVD, left ventricular hypertrophy and atherosclerosis, have been associated with increased BMI in youth (Lauer and Clarke 1995). Studies with children and adolescents have also shown that adiposity is significantly related to the presence of atherosclerotic lesions (Berenson et al. 1998; McGill et al. 2001). In 1996, Mahoney and associates reported that increased adiposity during childhood was linked to increased risk for developing coronary artery calcium deposits in young adulthood. In the Bogalusa study, youth with an increased number of risk factors such as overweight, high blood pressure and high cholesterol were at a significantly greater risk of developing atherosclerosis (Berenson et al. 1998). These studies provide important evidence regarding the potential pathways by which obesity can harm the heart and blood vessels and thereby increase risk of CVD across the lifespan.

Overweight and obesity also pose serious psychosocial consequences. Generally, youth who are overweight are more likely to report body dissatisfaction, physique anxiety, lower perceptions of competence, and are less likely to engage in health-promoting behaviours such as physical activity (Dietz 1998; Must and Strauss 1999; Sabiston et al.

2007). Overweight and obese youth are also more likely to develop an undesirable body image and poor self-esteem (Corbin et al. 1997; Dietz 1998), which can lead to a vicious cycle of low self esteem, high physique anxiety, and increased likelihood of partaking in health risking behaviors (e.g., very low-calorie diets or consumption of weight-loss/diet products, which are typically ineffective, resulting in greater weight gain). While researchers have highlighted the various ways in which excess body weight and resulting body concerns can impact health among the majority of the population, few have extended this research to include Aboriginal populations. Two American surveys have shown that many American Indian adolescents report weight dissatisfaction, low body pride and weight concerns (Neumark-Sztainer et al. 1997; Story et al. 1994). In Northern Canada, Gittelsohn and colleagues (1996) showed that 61.3% of a total 729 individuals living in an Ojibway-Cree community desired a thinner shape and only 16% were satisfied with their current body composition. More recent work by Fleming and colleagues (2006) highlighted the complexity of Aboriginal women's body-related emotional experiences and suggested that such experiences may not be as negative as previous research has led us to believe. Nonetheless, the psychosocial consequences of obesity in childhood and adolescence have the potential to be as debilitating as those of a more physiological nature and cannot be ignored.

In summary, adiposity, overweight and obesity can result in numerous physical and psychosocial health consequences. Central adiposity and obesity may accelerate disorders such as hypertension, insulin resistance, left ventricular hypertrophy and atherosclerosis, which can lead to the development of metabolic and cardiovascular diseases. Given that increased waist circumference and insulin resistance are major risk factors for the MetS, which is associated with the development of CVD and T2D, the prevention of central adiposity and obesity in youth is critical (Grundy et al. 2005).

2.4.2 Health Consequences of Obesity for Aboriginal Peoples

Research suggests that the consequences of adiposity and obesity may vary by ethnicity. Findings with Navajo youth showed 10% of *normal weight* boys and 6% of *normal weight* girls in the study had high blood pressure and *overweight* Navajo youth had even higher blood pressures (Gilbert et al. 1992). Among Navajo adolescents (12 – 19 years), excess body weight has been associated with higher lipids, lipoproteins, blood pressures and glucose levels, and a fivefold greater risk for elevated triglycerides compared to non-Aboriginal adolescents with the same degree of excess weight (Freedman et al. 1997). While Canadian data comparing similar measures (such as blood pressures) of overweight and non-overweight Aboriginal and non-Aboriginal youth are lacking, it is possible that the consequences of adiposity and obesity could be as severe.

In Canada, data from Aboriginal adults has shown that obesity is manifested by the onset of T2D (Bobet 1998) and extremely high prevalence rates of MetS (Young et al. 2000). Type 2 diabetes (T2D) has become a disabling and deadly disease for many Canadians, but in Aboriginal populations, the age and sex adjusted prevalence of T2D is three to five times higher than the general Canadian population (Bobet 1998). Within the past few decades, T2D has reached epidemic proportions in Canadian Aboriginal populations (Harris et al. 1997; Young et al. 2000), with rates in the off-reserve population substantially higher than that in the total Canadian population (Bobet 1998; Health Canada 2005). In 2001, for example, the Aboriginal Peoples Survey (APS) found the age and sex adjusted prevalence of T2D among a representative sample of off-reserve Aboriginal people to be 9% compared with 3.1% in the general population (Bobet 1998). Data from Aboriginals living on-reserve suggests that the prevalence of T2D is even higher than those living off-reserve (Harris et al. 1997; Pioro et al. 1996). Health Canada (2005) considers T2D to be of enormous concern to Aboriginal peoples owing to a variety of factors including "…earlier onset, greater severity at diagnosis, high rates of complications, lack of accessible services, increasing trends, and the increased prevalence of risk factors for a population already at risk."

Type 2 diabetes in youth was first recognized in the early 1980s (Dean et al. 2002), and in Canada, the majority of youth affected are Aboriginal youth (Dean et al. 2002; Fagot-Campagna et al. 2000). With an even greater prevalence of T2D relative to youth from the general population, estimates of T2D in Aboriginal youth are as high as seven-fold greater than the prevalence of type 1 diabetes in Caucasian youth (Campbell 2002; Dean 1998; Fagot-Campagna et al. 2000). In Manitoba, Aboriginal youth account for 98% of the youth with T2D (Dean et al. 2002). A Canadian study on Ojibwa-Cree youth from remote Manitoba showed that, in addition to being overweight, 64% of girls and 60% of boys aged 4 to 19 were also at high risk of developing T2D (Young et al. 2000). In the past decade, clinicians have diagnosed T2D in Canadian Aboriginal children as young as 4 years of age (Dean et al. 1998), and it has been suggested that the age of onset is continually decreasing (Dean and Sellars 2003; Young et al. 2000). Furthermore, the prevalence of T2D has increased so dramatically among children and adolescents (Dean et al. 2003; Dean 1998; Harris et al. 1996; Young and Rosenbloom 1998) that the term *youth type two diabetes* (Y2D) has been coined.

While the cause of T2D is considered to be multifactorial, several trends have become accepted and some genetic markers have been identified. Gestational diabetes is increasingly being recognized as a risk factor for youth to develop T2D later in life (Rodrigues et al. 1999), as is obesity, physical inactivity and familial diabetes (Canadian Pediatric Society 2005). In addition, studies such as the Sandy Lake First Nation study (Hanley et al. 2000) have revealed genetic markers that may be associated with diabetes (Hegele 2001).

2.4.3 Economic Consequences

Coupled with the health consequences of obesity, there is also an economic burden as a result of direct and indirect costs associated with obesity (Katzmaryzk and Janssen 2004). In 1997, Birmingham and colleagues reported that obesity among adults and youth in Canada accounted for $1.8 billion of the total direct health care expenditures; however, indirect costs were not reported (Birmingham et al. 1999). More recently, Katzmarzyk and Janssen (2004) conducted an analytical review to show the estimated cost associated with obesity among Canadians was $4.3 billion (Katzmarzyk et al. 2004). Combined with the above evidence regarding the health-related consequences, it is clear that the obesity epidemic will inevitability place a burden on the Canadian population and the healthcare system in present and future.

2.5 ASSESSMENT OF OVERWEIGHT, OBESITY AND ADIPOSITY IN YOUTH

Assessment of body composition is extremely challenging because no direct method exists other than in vivo neutron activation analysis and chemical analysis of the cadaver (Goran 1998). The lack of direct methods has led to the development of various models and several indirect methods to assess body composition. The most common indirect method to predict body composition separates the body into two compartments: fat mass (FM) and fat free mass (FFM). A limitation of these indirect methods is that they are based on a number of assumptions (e.g., hydration of FFM and density of FM) which are influenced by age and maturation (Lohman 1996). Sex, ethnicity and illness may also violate these assumptions; in addition, measurement error may limit their accuracy. Nonetheless, due to the associated disadvantages of more expensive, labor-intensive, complicated lab techniques, indirect methods which are clinically convenient, reliable, and non-obtrusive have been commonly used to measure body composition. The following section outlines some indirect measures for assessing overweight and adiposity.

2.5.1 Body Mass Index (BMI)

Height and weight, the most basic indicators of growth and nutritional status, are often used to develop indices that represent body composition. The body mass index, referred to as BMI, is determined from the formula, weight in kilograms divided by height in meters squared ($kg \cdot m^{-2}$), to predict normal weight (NW), overweight (OW) or obesity (OB) classifications. For classification in adults, a BMI quotient of 18.5 to 24.9 is considered normal weight (NW), 25.0 to 29.9 is considered overweight (OW) and 30.0 or more is considered obese (OB), based on health risks associated with these categories (World Health Organization 2003).

The aforementioned BMI classification standards in adults are not applicable for assessing youth. Growth charts that provide BMI reference values for youth are used as a means for comparing a child's BMI to that of other children who are the same sex and age using percentiles. The 50^{th} percentile is considered the average BMI for a child of that age; if a child's BMI is at the 95^{th} percentile, it means that their BMI meets or exceeds the BMI measurements of 95 percent of children that age. Historically, age- and gender- specific 85^{th} and 95^{th} percentiles of national reference data were employed as cut-points to determine OW and OB in children using U.S. National Health and Nutrition Examination Survey (NHANES) data. However, the U.S. Centers for Disease Control and Prevention (CDC) (Kuczmarski et al. 2000) recently revised these reference standards according to age- (by month) and sex-specific 85^{th} and 95^{th} percentiles (i.e., BMI growth charts) for youth (2 to 19 yrs) based on data from five national health examination surveys (http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/charts.htm). In Canada, the CDC growth charts have been recommended by the 2006 Canadian Clinical Practice Guidelines on the Management and Prevention of Obesity in Adults and Children to screen children and adolescents for overweight ($\geq 85^{th}$ to $< 95^{th}$ percentile) and obesity ($\geq 95^{th}$ percentile) in clinical settings (Lau et al. 2007).

More recently, a second method of classification was developed for use in children and adolescents (Cole et al. 2000). In 1998, sex- and age- specific BMI cut-points from the International Obesity Task Force (IOTF) were derived from a large international sample of six countries (i.e., United States, Great Britain, the Netherlands, Brazil, Hong Kong, and Singapore) by constructing centile curves that correspond to the adult BMI cutoffs for normal weight (≤ 24.9 kg/m^2), overweight (25 – 29.9 kg/m^2) and obese (≥ 30 kg/m^2) (Table 3). In addition to providing age- (6 month intervals) and sex-specific cut-off points (i.e., 90^{th} and 97^{th} percentiles) that make them sensitive to children (Cole et al. 2000), the IOTF reference

Table 3. Recommended International Obesity Task Force Cut-offs for Body Mass Index

Age (years)	Overweight		Obese	
	Males	Females	Males	Females
2	18.41	18.02	20.09	19.81
2.5	18.13	17.76	19.8	19.55
3	17.89	17.56	19.57	19.36
2.5	17.69	17.4	19.39	19.23
4	17.55	17.28	19.29	19.15
4.5	17.47	17.19	19.26	19.12
5	17.42	17.15	19.3	19.17
5.5	17.45	17.2	19.47	19.34
6	17.55	17.34	19.78	19.65
6.5	17.71	17.53	30.23	20.08
7	17.92	17.75	20.63	20.51
7.5	18.16	18.03	21.09	21.01
8	18.44	18.35	21.6	21.57
8.5	18.76	18.69	22.17	22.18
9	19.1	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24	24.11
10.5	20.2	20.29	24.57	24.77
11	20.55	20.74	25.1	25.42
11.5	20.89	21.2	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	21.27	22.98	27.25	28.2
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.3	29.11
15.5	23.6	24.17	28.6	29.29
16	23.9	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.7	29.41	29.69
17.5	24.73	24.85	29.7	29.84
18	25	25	30	30

Adapted from Cole et al. (2000). Data are based on six nationally representative cross-sectional samples of youth from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States.

cut-offs are also useful for international comparisons in population based studies (Lau et al. 2007). Thus, this method of classification has also been endorsed in Canada (Lau et al. 2007). At present, both the CDC reference and IOTF references are routinely used to assess childhood obesity as per the 2006 Canadian Clinical Practice Guidelines on the Management and Prevention of Obesity in Adults and Children (Lau et al. 2007). Although researchers suggest that there may be a need for ethnic-specific standards for Aboriginal children (Ball and Willows 2005), Lear et al. (2007) have shown current anthropometric thresholds (for adults) are appropriate for use in the Canadian Aboriginal population. Additionally, a number of Canadian studies have used the CDC and IOTF reference standards to assess overweight and obesity in Aboriginal youth (Downs et al. 2008; Hanley et al. 2000; Horn et al. 2001; Katzmarzyk 2008). For the purposes of this thesis, the IOTF reference were applied (refer to chapters three and four for details).

Despite the fact that it is quick, inexpensive and easy to use, BMI as a sole indicator of overweight or obesity is limited in that the timing and tempo of the pubertal growth spurt during adolescence are potentially confounding variables (Malina and Katzmarzyk 1999). BMI also does not differentiate between fat and fat free mass and when used exclusively, does not distinguish between body fat distribution profiles (Lear 2005). For example, if an athletic individual was assessed using BMI only, they may be considered obese by their high BMI, due to a large amount of lean body mass. Furthermore, changes in BMI over time may be more attributable to changes in skeletal muscle rather than changes in body fat; therefore, BMI may not be a good indicator of change in body composition over time. Despite its limitations, however, BMI has been validated against calculations of body density (Pietrobelli et al. 1998) and has high specificity as an indicator of overweight and obesity based on analyses of several ethnically diverse adolescents (Malina and Katzmarzyk 1999). Combined with its low cost and simplicity to use, BMI is generally accepted as a valid and reliable indicator of total adiposity and health risk among adults and children (He and Beynon 2006; Lau et al. 2007) and can be used in combination with an indicator of body fat distribution to accurately assess health risk.

2.5.2 Waist Circumference (WC)

Waist circumference (WC) is a simple, effective measure of body fat distribution (Daniels et al. 2000) as the equipment needed (i.e., a flexible tape measure) is inexpensive and extremely portable. WC is also useful for estimating health risk (Maffeis et al. 2001), as several studies have shown that it is strongly associated with risk factors for coronary heart disease (Maffeis et al. 2001; Savva et al. 2000). For example, research has shown that it is central adiposity (CA) rather than total adiposity that is often associated with a worse cardiovascular risk profile, T2D or other metabolic abnormalities (Daniels et al. 1999; Despres and Lemieux, 2006; Maffeis et al. 2001). Measured WC may also help identify youth at high risk for MetS (Sellars et al. 2008), since WC is considered to be a good anthropometric indicator of visceral adipose tissue (and therefore central adiposity) (Rankinen et al. 1999). Past research indicates that measures such as the waist to hip ratio (WHR), BMI and WC are all correlated with CVD risk factors, intra-abdominal fat, and mortality (Calle et al. 1999; Pouliot et al. 1994); however, WC has a stronger correlation with CVD risk factors and intra-abdominal fat than WHR or BMI (Rankinen et al. 1999; Savva et al. 2000). WC also has excellent reproducibility and is a more reliable measure than WHR (Daniels et al. 2000). Therefore, measuring WC in combination with BMI is important to assess health risk and provide a reference point to monitor progress over time (Katzmarzyk 2004; Lau et al. 2007).

Smoothed and weighted age and sex-specific WC percentiles (5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th}) were recently developed for Canadian youth (11 – 18 yrs) using regression (Katzmarzyk 2004). Although no claim can be made to determine an 'optimal' WC threshold, these percentiles can be used to place the sample within a national (i.e., Canadian) context (Katzmarzyk 2004). Moreover, these reference data can be used provisionally to identify abdominally obese youth using the 90^{th} or 95^{th} percentile to denote those youth with a high WC relative to their age and sex matched peers (Katzmarzyk 2004). These cut-points are supported by the work of Maffeis et al. (2001) who suggest that youth with a WC greater than the 90^{th} percentile may be more likely to have multiple risk factors than youth with a WC that was less than or equal to the 90^{th} percentile. While these reference standards are an improvement in Canada, further work needs to be done to develop population based standards for children younger than 11 years or older as well as ethnic-specific WC cutoffs.

A second commonly used classification method of WC is the NHANES III reference (http://www.cdc.gov/nchs/data/nhanes/t47.pdf). These data provide reference percentiles for youth (2 - 19 years) to classify individuals as NW, OW or OB. While these standards also do not have established cut-points, a WC that meets or exceeds the 85th percentile has been used to identify those youth who are at risk of overweight and who have a high WC relative to their age and sex matched peers (Downs et al. 2008). For the purposes of this thesis, the NHANES III reference data were applied (refer to chapter three and chapter four for more detail).

2.5.3 Dual Energy X-ray Absorptiometry (DXA)

One technique that divides the body into multiple compartments to measure bone mineral and soft tissue composition is dual energy x-ray absorptiometry (DXA). This method divides the body into three compartments: 1) fat mass; 2) fat free mass (total body water); and 3) fat free mass (fat free dry mass including bone mineral, protein, glycogen, and soft tissue mineral) (Malina and Bouchard 2004). Given that the tissue in each of the three compartments vary in density, the dual energy beams that are emitted in the scan are broken down differently in each compartment (Malina 2002). Although DXA involves radiation exposure, it is extremely low (0.015 mGy) (Hologic Discovery Operators Manual 2002).

Since variability in bone mineral density is a primary source of error in estimating fat free mass, DXA is more accurate than two-compartment model techniques such as hydrodensitometry or air plethysmography. Compared to bioelectrical methods and anthropometric methods of body composition assessment, it has the added advantages of being independent of sample based prediction equations and available at a moderate cost.

A general limitation of many widely used body composition assessment methods is the lack of true validation studies that have performed comparisons with known chemical composition (Goran 1998). Chemical analysis of the carcass is ideal for comparing body composition techniques because the whole animal model simulates the various body composition compartments of the living organism. Due to practical and ethical issues, studies with human cadavers are limited; hence pigs often are used since their body fat content is similar to that of humans. The advantage of using DXA is that several studies have demonstrated its validity in adults and children by comparison with a pig model (Ellis et al 1994; Pintauro et al. 1996). DXA has also been validated against hydrodensitometry, which has been considered the standard for measurement of fat mass (Morrison et al. 1994) and has been shown to provide reliable measurements in adults and children (Chan 1991; Gutin et al.

1996; Morrison et al.1994). Despite the lack of established reference standards to denote total or central adiposity, this method is considered the gold standard or criterion method to assess body composition, and can be employed in a variety of populations ranging from geriatrics to pediatrics.

2.6 THE ENERGY BALANCE EQUATION

Body weight is ultimately the result of energy balance. The law of thermodynamics suggests that the energy entering a system minus the energy leaving a system will be equivalent to the amount of stored energy. Accordingly, energy can be changed from one form to another, but cannot be created nor destroyed. In the human body this means any persistent difference between energy taken in and energy expended will be reflected by a change in energy stores. This law provides the basis for the energy balance equation. In its simplest form, the energy balance equation can be stated as: Energy stores = Energy intake (EI) – Energy expenditure (EE) (Thompson et al. 2007) (Figure 2). In a healthy individual, the systems and mechanisms that regulate energy balance are quite precise (Lustig 2001). If energy intake (simply the energy we obtain from the food we eat) consistently exceeds energy expenditure, there will be a positive energy balance, which over time, will likely result in stored fat (Thompson et al. 2007). Energy stored in the tissues of the body in the form fat exists as triglyceride stored in adipose tissue cells (adipocytes) both subcutaneously and viscerally, although very small pools also exist as triglyceride in the small intestine, liver, intramuscular (IMTG), and as free fatty acids (FFA) in the plasma. Increased central or total adiposity may therefore result from either high-energy intake or low energy expenditure, or a combination of the two (Thompson et al. 2007).

Figure 1. The Energy Balance Equation

ENERGY IN = ENERGY OUT → Weight Maintenance

ENERGY IN > ENERGY OUT → Weight Gain

ENERGY IN < ENERGY OUT → Weight Loss

Total energy expenditure (TEE) consists of 3 components: 1) basal metabolic rate (BMR); 2) energy expenditure due to physical activity (PAEE); and 3) the thermic effect of food (Thompson et al. 2007). Basal metabolic rate (BMR) can be defined as the energy expended by an individual 10 to 12 h post absorptive, lying awake in a thermoneutral environment and not subject to any emotional and physical stress (Shetty et al. 2004). However, if the environment is not strictly thermoneutral, or the subject experiences small amounts of emotional or physical stress, then the term resting metabolic rate (RMR) should be applied (Shetty et al. 2004). In adults, BMR typically makes up 60 to 70% of an individual's TEE (Thompson et al. 2007), although in very active individuals, such as athletes, this may be less (Ravussin et al. 1986). The concern in today's society is that many individuals are living very sedentary lives, and consequently, BMR or RMR most likely comprises the majority of TEE.

Physical activity energy expenditure (PAEE), the most variable component of energy expenditure, is considered to be any voluntary movement of the skeletal muscles and support systems, and is largely determined by the mode, duration and intensity of physical activity performed and the efficiency by which it is performed (Hill and Sarris 1998). The energy used for physical activity includes physical activities associated with daily living (e.g. walking, climbing stairs), extra activities associated with recreational exercise outside normal routines (e.g. going for a run, playing basketball), and unplanned muscular activities (e.g. fidgeting or shivering). Physical activity provides the greatest source of between and within–subject variation in daily energy expenditure in normal healthy adults (Black et al. 2004). Studies have shown that physical activity can account from 15% (sedentary individuals) to 50% (very active individuals) of total energy expenditure (TEE) (Black et al. 2004). Physical activity can be expressed as the amount of work performed (watts), time period of activity (min), units of movement (counts), or numerical scores from questionnaires (Hill et al. 1998). Given that energy expended through physical activity is somewhat dependant on body size, physical activity is typically expressed as multiples of resting metabolic rate on an activity–specific basis (referred to as METs). The term *METs* is therefore the energy expended in an episode of physical activity (expressed relative to RMR) during the duration of that physical activity. For example, walking is approximately 2.0 METS and running at 5mph approximately 8.0 METs.

The final component of TEE is the thermic effect of food (TEF). This is defined as the energy required to process food through digestion, absorption, transportation, metabolization and storage (Thompson et al. 2007). Of the three TEE components, TEF is estimated to contribute a relatively small proportion (5-10%), with resting metabolic rate and energy expenditure from physical activity contributing the most to total energy expenditure. Thus, for the purposes of this paper, the thermic effect of food will not be further discussed.

2.7 FACTORS ASSOCIATED WITH ADIPOSITY, OVERWEIGHT AND OBESITY

Although body weight is predicted by the energy balance equation, many factors have been implicated in the current obesity trend (Parsons et al. 1999; Salbe and Ravussin 2000). Overweight is generally associated with lifestyle behaviors (such as diet and physical activity, which occur in the context of environmental factors), while obesity typically has a stronger genetic etiology (Bouchard 2000b). Table 4 summarizes these factors and the following literature review will further discuss the factors pertinent to this thesis dissertation.

Table 4. Factors Associated With Overweight (OW) and Obesity (OB)*

Category and Factor	**Explanation**
Biological	
Chronological age	Childhood obesity (OB) is a risk factor for adult obesity
Biological age	Changes in adiposity coincide with biological maturity according to sex
Sex	Females have more body fat than males and generally have a more gynoid distribution of fat compared to males
Ethnicity	The prevalence of OW/OB varies among ethnic groups within a population
Social	
Parental OW/OB	Parental OW/OB increases the likelihood of OW/OB in the child
Socio-economic status (SES)	There are more obese in the high SES in developing countries There are more obese in the low SES in developed countries
Behavioral	
Energy intake	Chronic excess caloric intake causes weight gain and may lead to obesity Other dietary factors (e.g., carbohydrate intake) may be associated with body weight
Physical activity (PA)	A low level of physical activity is a risk factor for weight gain Sedentary behavior is on average higher in obese individuals Regular PA may contribute to weight loss and weight maintenance and alter body composition by reducing total and central adiposity High levels of PA increase sympathetic nervous system activity and resting metabolic rate
Television viewing	The more hours spent viewing T.V. daily, the greater the likelihood of obesity
Metabolic/endocrine	
Resting Metabolic Rate (RMR)	A low body weight and composition adjusted RMR is a risk factor for weight gain, but contradictory data have been reported OW and OB individuals have higher absolute RMR
Thermic response to food	OB individuals have a depressed response in some studies, but contradictory results are common
Blood leptin level	Low leptin levels are related to weight gain but contradictory results have been reported Most OB individuals have high leptin levels

Table 4. Factors Associated With Overweight (OW) and Obesity (OB)*

Factor	Trends and comments
Metabolic/endocrine continued	
Insulin sensitivity	Obese individuals are often insulin resistant and hyperinsulinemic
Growth hormone levels	Low growth hormone levels is a risk factor for weight gain
Adipose tissue metabolism	Catecholamine-induced lipolyisis is reduced in obesity Lipogenesis from glucose is increased in adipose cells of obese
Skeletal muscle metabolism	Proportion of type I skeletal muscle fibers is unaffected by obesity Proportion of type IIb skeletal muscle fibers is often elevated in obesity

*Adapted from Bouchard (2000b) and other various sources

2.7.1 Biological Factors

2.7.1.1 Ethnicity

While a detailed review regarding genetics and obesity is beyond the scope of this thesis, a general discussion is warranted since genetic background has the potential to account for as much as 80% of the variation in body composition (Clement 2005; Farooqi and O'Rahilly, 2007). Studies of adoptees and twins, for example, confirm that a large part of the variability in body size and composition can be attributed to genetics (Maes et al. 1997; Stunkard et al. 1990). Beamer (2003) suggests that multiple genes contribute to varying degrees of obesity. While these genes may account for only a small fraction of the number of cases of obesity, they confirm that obesity can be strongly influenced by genetics. However, while genetic factors may increase the susceptibility for obesity, the gene pool does not change at a rate rapid enough to explain the recent rise in obesity (Daniels 2006); this is further indicated by the fact that most Aboriginal communities have developed obesity only in the past two generations (Anand et al. 2007). Thus, most cases of obesity in the Aboriginal population may be due less to genetics and more to genetic influences that manifest themselves in the context of the environment (Beamer 2003; Farooqi and O'Rahilly 2007).

The Aboriginal population is one of the best examples of a population possibly genetically susceptible to developing obesity in the context of our westernized environment, given the increase in obesity rates among this population over the last half century (Young et al. 2000). The 'thrifty genotype hypothesis' (Neel 1962) is the most widely known theory proposed to explain the relationship between genetic susceptibility and the environment. While the exact mechanism(s) is/are unknown, the 'thrifty genotype hypothesis' suggests that the dramatic increase in obesity in Aboriginal peoples in recent decades is the result of a shift from historic feast-famine cycles to the current period of continuous and ample food supply. Traditionally, Aboriginal peoples lived a nomadic "hunter-gatherer" lifestyle with high protein, low carbohydrate diets and high levels of physical activity. Given that food was not always available their bodies became very efficient at storing energy during times of famine, developing a "thrifty" metabolism. In Westernized societies today, there has been a general decline in energy expenditure through physical activity due to a shift from an agricultural to a manufacturing economy. This has created an average lifestyle where less energy is expended through laboring and food acquisition, resulting in decreased occupational physical activity

(Abelson and Kennedy 2004; Stein and Colditz 2004). Combined with a “thrifty” metabolism, this transition from a traditional “hunter-gatherer” lifestyle to a sedentary lifestyle that contains more high carbohydrate foods (Harris et al. 1997; Trifonopoulos et al. 1998) is believed to have contributed to the rise in obesity and T2D in Aboriginal people today (Harris et al., 1997). This hypothesis implies that Aboriginals populations may have greater genetic susceptibility to overweight and obesity when predisposed to an ‘obesogenic’ environment (i.e., an environment that encourages excessive energy intake and little or no physical activity) compared to those of other genetic backgrounds.

While the thrifty genotype theory provides an intriguing hypothesis to explain the increase in obesity in the Aboriginal population, there are numerous other physiological factors that influence energy balance (i.e. those influencing appetite, energy expenditure, lipid metabolism, insulin sensitivity) (Beamer 2003). Neel himself has acknowledged that his original hypothesis was overly simplistic (Neel 1999). For example, this hypothesis did not consider changes in body composition that have been observed over time, such as the shift from greater muscle mass to greater fat mass, thus producing different effects related to insulin sensitivity (i.e. skeletal muscle has an increased sensitivity to insulin compared to fat mass) (Neel 1999). Furthermore, obesity may be related to a change in the type of food (carbohydrate) consumed (i.e., foods with a higher glycemic index) rather than the endless food supply.

Despite reservations regarding the thrifty genotype hypothesis, community-specific studies in Canada have explored the possibility of a thrifty genotype among the Aboriginal population within the context of T2D. Some of the most extensive genetic testing on T2D in the Aboriginal population has been conducted in Sandy Lake (Hegele 2001), an Oji-Cree community in Northern Ontario with the third highest prevalence of T2D in the world (Harris et al. 1997). In this community, genetic mapping and candidate gene sequencing (an educated guess regarding which genes may be involved in weight regulation and subsequently searching these genes for mutations) (Beamer 2003) were used to identify genes susceptible to T2D (Hegele 2001). Genetic associations have also been documented in other Canadian Aboriginal populations (Dean 1998).

2.7.1.2 Biological maturity

The complexity of factors summarized in Table 4 can be obscured by normal growth and maturation. While all children follow the same pattern of growth and development from birth to maturity, the timing and tempo is different in each child. Childhood is characterized by relatively stable growth whilst adolescence is characterized by rapid changes in body size, shape and composition (Rogol et al. 2002). Three periods have been suggested as sensitive or "at risk" for the development of overweight and obesity in adulthood: 1) the prenatal period; 2) the period of adiposity rebound (AR); and 3) adolescence (Dietz 1997). In addition, breast feeding during infancy has been shown to have a protective effect on the later development of overweight and obesity (Butte 2001). The association between the prenatal period and overweight and obesity in adulthood is based on links between birth weight and adult BMI. For example, low birth weights and high birth weights (indicative of fetal under nutrition or over nutrition, respectively) have been associated with a greater risk of being overweight or obese in adulthood (Serdula et al. 1993). The exact mechanisms to explain these associations remain unclear, and despite the evidence, studies also indicate that many overweight/obese adults have birth weights in the normal range, such that neither of the above hypotheses is supported (Serdula et al. 1993). The adiposity rebound (AR), the second period of risk for adult overweight and obesity, is an estimated point in time characterized by accelerated growth in BMI after it reaches its nadir typically occurring between 5 and 8 years of age (mean age is around 6 years) (Rolland-Cachera et al. 1984). Available data suggest that individuals who have an earlier AR (i.e. <5.5 years) tend to, on average, have greater adiposity in adolescence and higher BMIs in young adulthood (Rolland-Cachera et al. 1984). Adolescence is the third period of growth considered to be linked to the development of overweight/obesity and is most relevant to this thesis. For example, in the Fels Longitudinal Study, the maximum growth rate of the BMI and the BMI at maximum velocity during adolescence were associated with overweight at age 35 – 45 years in both sexes (Guo et al. 2000).

Early sexual maturation has been consistently related to increased body weight in adolescents and young adults, particularly in girls (Freedman et al. 2003; Wang 2002). Large retrospective studies, for example, have shown that among young female adults, those who experienced earlier onset of puberty and earlier menarche (i.e., before the age of 12) were heavier and fatter than later-maturing girls. Similarly, early maturing boys tend to have, on average, more weight for height, and in turn, a higher BMI during childhood, which persists through adolescence (Malina and Bouchard 2004). However, the elevated BMI in boys is related to both increased lean and fat mass. Early maturation in males has also been associated with a proportionally greater accumulation of subcutaneous fatness on the trunk, as boys of advanced maturity have more central adiposity, not only during adolescence, but also in young adulthood. It has been suggested that the earlier a child is fat, the fatter the child; and that the earlier a child is fat, the earlier the child will be fat at a later age (Guo et al. 2000; 2002). Furthermore, the fatter a child is at one age, the fatter that child will be at a later age (Guo et al. 2000). Thus, the tempo and timing of the development and distribution of fat seem to be associated with increased risk of total and central adiposity in adulthood in both girls and boys (Malina 2002).

As children mature into adolescents, levels of estrogen, testosterone, and growth hormone rise and body fat tends to shift from peripheral to central regions and from subcutaneous to internal sites in the body. These hormones can therefore have a profound impact on body fat deposition and distribution (Ball and McCargar 2003). The accumulation of body fat and changes in the relative distribution of fat, both subcutaneous and visceral, associated with differential timing of sexual maturation are consequently related to overweight/obesity. Given that children of the same chronological age may vary significantly in their biological maturity (Malina 1996), it is critical that obesity research control for the normal effects of normal growth and maturation.

2.7.1.3 Sex

A natural consequence of adolescence (and resulting changes in the level of hormones) is the laying down of adipose tissue, the structural and functional component of fat mass (FM). Unlike fat free mass (FFM) (i.e., skeletal and lean tissue), which follow the general growth patterns of height, fat mass develops its own unique pattern of growth (van Lenthe et al. 1998) and these changes are sexually dimorphic (Malina and Bouchard 2004). For example, absolute FM increases more rapidly in girls than in boys after about 6 years of age, and during adolescence, increases at a rate almost twice that of boys. FM continues to increase throughout adolescence in girls, but in boys appears to reach a plateau or to change only slightly near the time of the adolescent spurt (about 13 – 15 years). In contrast to fat free mass (FFM), females have, on average, about two times the FM of males in late adolescence and young adulthood.

Like absolute FM, percentage body fat (i.e., relative FM) also varies according to sex during adolescence. After early childhood, girls typically have greater relative FM (i.e., FM makes up a greater percentage of body weight) than boys at all ages since relative FM increases gradually through adolescence in the same manner as absolute FM. Relative fatness in males also increases gradually until just before the adolescent spurt (about 11 – 12 years), when it gradually declines. Thus, in contrast to absolute FM, relative FM declines among males during adolescence. This decline in percent fat is due to the rapid growth of FFM, whereas growth of FM is much slower, therefore contributing to a lesser percent of body weight at this time. Hence, males gain almost twice as much FFM as females over the adolescent span, while females gain more than twice as much FM as males. The net result is a decline in relative fatness in males and an increase in relative fatness in females.

In addition to changes in the absolute and relative amount of fat in the body during growth, major changes in fat distribution occur during childhood and adolescence due to normal growth and development (Malina and Bouchard 2004; Thompson et al. 2002). Fat distribution is the placement of fat depots on the body, and is of considerable clinical interest since variation in the distribution of fat is linked to the development of several diseases such as CVD and T2D (Despres et al. 2006). The reason for this increased risk of chronic disease is that fat depots in different areas of the body also differ in their metabolic characteristics. Visceral fat distributed internally (deeply) around the trunk and abdominal region, for example, is much more metabolically active and is therefore of greater health risk than subcutaneous fat distributed around the hips and limbs (Despres et al. 2006).

The extent of change in fat distribution in children and adolescents is masked by the individuality of timing and tempo of the adolescent growth spurt and sexual maturation, even among youth of the same sex and ethnic background (Malina and Bouchard 2004). In general, males accumulate proportionally more subcutaneous adipose tissue on the trunk during adolescence compared to females. In terms of central adiposity, a sex difference seems to occur during late adolescence when males accumulate proportionally more visceral adipose tissue than females. These changes in the distribution of body fat (i.e., central vs.

peripheral) result in the typical android and gynoid patterns of fat distribution of the older adolescent and adult (Roemmich et al. 1997). Thus, research assessing body fat and its distribution should do so in relation to sex.

2.7.2 Behavioral Factors

2.7.2.1 Physical Activity

Physical activity, broadly defined as any bodily movement produced by the skeletal muscles that results in energy expenditure (Caspersen et al. 1985), is the most variable component of day-to-day energy expenditure (Thompson et al. 2007). Traditionally, it was assumed that children required similar amounts of physical activity as adults. However, it is now known that physical activity levels required for health in adults are not the same as those required for health in children, and consequently, physical activity guidelines for youth have been established. For example, the United States (Corbin and Pangrazi 2004; US Department of Health and Human Services & US Department of Agriculture 2005), United Kingdom (Department of Health 2004) and Australia (Australian Government 2005b) recommend that youth engage in at least 60 minutes of moderate intensity (i.e., physical movements that make one breathe hard and require an effort to at least that of brisk walking (Bar-Or and Rowland 2004)) daily physical activity. Like the U.S., U.K. and Australia, Canadian recommendations for physical activity in youth suggest 60 minutes daily, but these recommendations are based on increments and current physical activity status (Health Canada 2002a, 2002b). For example, the Canadian Physical Activity Guide for Children and Youth suggests that physically inactive youth increase the amount of time they currently spend doing physical activity by at least 30 minutes per day. However, because 60 minutes of daily physical activity should be considered a *minimum* amount, Canada's guidelines also recommend that, after several months, youth accumulate at least 90 minutes per day (i.e., 60 minutes of moderate intensity physical activity and 30 minutes of vigorous intensity physical activity). Although this guideline (i.e., 90 minutes daily) is significantly higher than the traditional 60 minute recommendation, it has been suggested that 90 minutes of daily physical activity may be required to prevent insulin resistance in youth (Andersen et al. 2006).

The concept of physical inactivity is less simple to define. Although the term implies the absence of physical activity, using the Caspersen and associates (1985) definition for physical activity above, physical inactivity can really only occur during sleep (Marshall and Welk 2008). Hence, a new concept of physical inactivity, called *sedentary behavior*, has emerged to reflect the diverse range of physically inactive behaviors. Although the assessment of sedentary behavior is varied, it typically involves sitting (Marshall and Welk 2008); for example, 'screen time', which includes any *leisure* time spent watching T.V., videos or DVDs and/or playing computer or videogames outside of school hours would be classified as physically inactive, sedentary behavior. Despite improved efforts to determine specific guidelines on the use of television and other electronics, recommendations for sedentary behavior for young people are less clear. However, it is generally agreed that young people, particularly elementary school children, should avoid prolonged periods of sedentary behaviour (Corbin and Pangrazi 2004), and the American Academy of Pediatrics (2007) recommends that total entertainment screen time for youth is limited to 2 hours per day (Marshall and Welk 2008). Canada has also adopted formal guidelines for reducing sedentary time (Health Canada 2002a; 2002b) which recommend that physically inactive youth reduce time spent watching T.V., playing computer games and surfing the internet by 30 minutes per day initially, to at least 90 minutes daily over several months (Health Canada 2002a; 2002b). The Canadian Physical Activity Guide for Children and Youth (2002) also suggests limiting time watching television or engaging in other sedentary activities to no more than 90 minutes per day; similarly, the 2006 Canadian Clinical Guidelines for the Prevention and Treatment of Obesity in children suggest limiting "screen time" to no longer than 2 hours per day (Lau et al. 2007).

Several assessment methods are available for measuring physical activity and sedentary behaviors. The selection of an appropriate method depends highly on the population being assessed and the relative importance of accuracy and reliability. Assessment methods for youth have been summarized in Tables 5 and 6.

With increased reliance on technology and fewer opportunities for daily physical activity, our modernized environment has reduced physical activity opportunities and increased time to be sedentary. Recently, Canada's Report Card on Physical Activity for Children and Youth (Active Healthy Kids Canada 2009) showed that nearly 9 out of 10 Canadian youth were not meeting recommendations set forth in Canada's Physical Activity Guide for Children and Youth (Health Canada 2002). With a grade of F for physical activity, the vast majority of youth were not attaining the recommended 90 minutes of moderate to vigorous activity daily (i.e., the equivalent of 16, 500 steps) (Active Healthy Kids Canada 2009). Research has also shown that Canadian youth undertake long periods of physical inactivity, with only 10% of Canadian youth (5-19 yrs) following the guideline for screen time (i.e., <2 hours per day) and the majority engaging in nearly 6 hours of sedentary screen time daily. Despite attention to the issue of increasing amounts of time Canadian youth spend in front of a screen, data suggests that Canadian youth spend, on average, 5 – 6 hours on weekdays, and 6-7.5 hours per day on weekends engaging in sedentary screen time (Active Healthy Kids Canada 2009). Thus, youth are spending too little time being physically active and too much time being sedentary.

Table 5. Techniques for assessing physical activity in youth

Type of Measure	Technique	Description	Advantages	Disadvantages
Criterion Measures	Indirect calorimetry	Involves measuring oxygen consumption as a proxy of energy expenditure	High reliability and validity	Limited use for measuring physical activity behavior as it is confined to a lab setting
	Doubly labeled water	Simple, noninvasive approach that requires ingestion of isotopic tracers	High reliability and validity for estimating energy expenditure	Very expensive; limited use for measuring physical activity behavior in youth as it is does not partition energy expenditure into its components
	Direct observation	Observation of activity in natural setting	Provide detailed information about level and context of activity; highly accurate	Require considerable time and effort; can be expensive
Objective Measures	Pedometers	An instrument worn on the hip that indicates step counts.	Estimate time spent moving; can recall data over time	Suited only for capturing locomotor behavior (walking); do not control for body size (and stride length)
	Accelerometers	A device worn on the hip that measures activity in 'epochs' by measuring the acceleration of body segments during movement	The accepted standard for most field studies in youth, these instruments provide an accurate, objective measure of physical activity; highly reliable and valid; excellent for group comparisons.	Inability to detect activities that involve upper body movements or capture increased energy required to carry a load up hill; costly relative to other methods; limited for use in individuals
	Heart rate monitors	Provides an indication of physical activity using measured heart rate	Reflects the true physiological stress on the body.	May introduce error given individual differences in heart rate response to activity; may be limited in field setting as a result.
	Multichannel activity monitors	A combination of techniques to integrate data from heart rate monitors and accelerometers	The combination of devices may increase accuracy in comparison to the use of one measure alone as it overcomes the limitations of each instrument.	May be expensive and are relatively new, therefore more research may be required as to their utility.
Subjective Measures	Self-report	Widely used, practical method for collecting physical activity information whereby an individual recalls their own behavior. Includes diaries, logs, interviews and questionnaires.	Inexpensive, quick, low subject burden, easy to administer	Rely on memory recall which introduces error; youth may misinterpret the question being asked; may be limited by cognitive abilities; may not capture intermittent activity in youth; require repeated measures for assessing physical activity patterns.

Table 6. Techniques for assessing sedentary behavior in youth

Type of Measure	Technique	Description	Advantages	Disadvantages
Criterion Measures	Direct observation	Observation of behavior in a natural setting	Provide detailed information about type and context of sedentary behavior; highly accurate, studies on T.V. viewing are highly reliable	May cause behavioral reactivity; requires considerable time and effort, therefore is often impractical.
Subjective Measures	Time use Diaries	Widely used, practical method for collecting information whereby an individual records what they do and for how long.	Inexpensive; moderate validity and reliability; successfully used in children as young as 6 years.	Intrusive to the participant; requires ongoing and detailed information kept for short periods.
	Self – report questionnaires and checklists	Usually obtained from paper and pencil methods or in person interviews where recall of frequency and duration of sedentary behavior over a specific time frame is required. Checklists of specific behavior are easy for children to understand	Cost –effective alternative ; can assess weekday and weekend behavior; simple, easy to administer; acceptable reliability	Retrospective in nature, therefore rely on memory recall which introduces error; children may misinterpret the question being asked; may be limited by the cognitive abilities of the participant; repeated recalls required to adequately capture typical behavior patterns; outcome measures based on aggregates of time may mask unique behavior-specific patterns. Few have been adequately assessed for reliability and validity.

While there is substantial evidence indicating sub-optimal physical activity levels of the general Canadian population, there are relatively few data on the physical activity levels of minority populations. In Canadian Aboriginal populations, for example, there is a paucity of physical activity data (Coble and Rhodes 2006; Young and Katzmarzyk 2007). While some evidence suggests that regardless of age, it is uncommon for Aboriginal people to engage in regular moderate-intensity physical activity (Fontvielle et al.1993; Hanley et al. 2000; Horn et al. 2001), more data are needed to fully understand the physical activity behaviors of Aboriginal populations, particularly among children and adolescents. In 2001, Statistics Canada conducted its second Aboriginal Peoples Survey (APS-2) with off-reserve Aboriginal youth and showed that 71% (aged 6 – 14 years) living in non-reserve areas participated in sports activities at least once per week (Statistics Canada 2004). A recent Canadian study that assessed physical activity using pedometers showed that less than half (i.e., 49%) of Cree youth (aged 9-12 years) were sufficiently active for health benefits and the majority (83%) had very poor physical fitness (Downs et al 2008; Ng et al 2006). Earlier work with James Bay Cree youth (grades 4-5 and 8-9) from Quebec reported a mean frequency of 2.7 physical activity sessions weekly (Bernard et al. 1995). Bernard and associates (1995) also reported that Cree youth spent an average of 13 hours per week watching T.V. and/or playing video games. These studies represent the extent of Canadian research investigating physical activity and sedentary behaviors in Aboriginal youth.

Although one would expect the rising rates of obesity in Canadian youth would be linked to reduced physical activity, definitive evidence showing a relationship between these two variables is limited (Marshall and Welk 2008). Some cross sectional studies have shown an inverse association between physical activity levels and BMI or body fatness in children and adolescents, but the associations are weak (Ekelund et al 2005; Ruiz et al 2006), and other studies have failed to identify any significant relationships (Goran et al. 1999; Molnar et al 2000). These diverging results may be the result of difficulties related to measuring physical activity levels accurately in youth. Self-reported questionnaires, heart rate monitors, doubly labeled water and motion sensors (pedometers or accelerometers) have all been used to study weight-related differences in physical activity; however, none of these methods is without limitations. A second explanation for the equivocal findings from research investigating physical activity, adiposity and/or obesity could be related to the reliance on measures such as

BMI. The use of an alternative method, such as DXA or waist circumference, could provide an indication of trunk adiposity (Dencker et al. 2006), which has been shown to be inversely related to physical activity (Kim and Lee 2009; Klein-Platat et al. 2005).

Despite the aforementioned inconsistencies and limitations in research examining the link between physical activity and adiposity, physical activity plays a powerful role in the prevention and management of obesity related conditions, such as T2D and cardiovascular disease (McGavock et al 2007). In youth, adiposity is a major determinant of T2D and is thought to be the most relevant modifiable clinical index of diabetes in youth (McGavock et al 2007). Additionally, some data do exist to suggest that insufficient physical activity is related to a higher BMI in adolescent boys and girls (Patrick et al. 2004). A Swedish study with children (8-11 years) found that total body fat (expressed as a percentage of body mass using DXA) was inversely related to minutes of vigorous physical activity using accelerometers, where children in the highest quartile for body fat performed an average of 12 minutes less of vigorous physical activity daily compared to their counterparts in the lowest quartile (Dencker et al. 2006). Research with adolescents also suggests that physical activity may be inversely related to waist circumference (Klein-Platat et al. 2005). Furthermore, observational and longitudinal studies have provided relatively convincing support for the hypothesis that reduced physical activity in the growing years is related to increased adiposity in young adulthood (Kimm et al. 2005).

Research investigating the relationship between adiposity and sedentary behavior in children has also been conducted and a positive relationship has been established (Eisenmann et al. 2002; Kaur et al. 2003; Robinson 2001). For example, Canadian data has shown that increased screen time (e.g., television, computers, movies, and electronic games) is related to an increased likelihood of becoming overweight and obese in children and adolescents (Shields 2005; Tremblay and Willms, 2003). A New Zealand longitudinal study examining the association between child and adolescent T.V. viewing and adult health found the prevalence of overweight was approximately 45 % in young adults who watched 2 to 3 hours of T.V. per weekday between the ages of 5 and 15, compared to 25% in those who watched less than one hour of T.V. per weekday during the same period (Hancox et al. 2004). Results from the 1000 individuals in this study from birth to 26 years also indicated that this relationship remained significant after adjusting for BMI at age 5 and physical activity at age

15, which suggests that it may be lowered metabolic rate during T.V. viewing or the adverse effects on diet (or both) rather than the displacement of physical activity per se which may explain the association between T.V. viewing and overweight or obesity (Ludwig et al. 2001).

Data from Aboriginal youth have indicated a higher degree of sedentary activities compared to non-Aboriginal youth, but studies investigating these behaviors in relation to ethnicity and adiposity are uncommon in the literature. An American study comparing Pima children (mean age 10 years) to their non-Native American counterparts found that Pima children spent significantly less time doing sport and leisure physical activities and more time watching television (Fontvielle et al. 1993). Canadian research showed overweight in Cree children was associated with lower physical activity and greater TV viewing (Bernard et al. 1995) and hours of T.V. viewing was a determinant of adiposity among Mohawk girls (mean age 7.5 years) (Horn et al. 2001). Similarly, a cross-sectional study with Oji-Cree youths aged 10-19 years found that five or more hours of T.V. per day resulted in a 2.5 fold increase in the risk of obesity (Hanley et al. 2000). Studies further documenting the prevalence of sedentary behaviors and exploring the relationship of sedentary behavior and adiposity in Aboriginal youth would be a useful contribution to the literature.

In Aboriginal communities, it is assumed that the transition into a more westernized lifestyle with reduced physical activity opportunities may be linked to hypokinetic diseases that are highly prevalent in the Aboriginal population in comparison to other ethnic populations (Health Canada 2005). While there is support for a relationship between physical activity and overall health and chronic disease risk, there is limited data on the physical activity levels of Aboriginal populations and studies describing the relationships between physical activity behaviors and adiposity development in Aboriginal youth are even more limited. Furthermore, aside from a recent Canadian study which indicated that the physical activity levels of Aboriginal youth (12 – 17 yrs) were not significantly different from their Caucasian peers (Katzmarzyk 2008), there is little data to support the finding that habitual physical activity levels in Canadian Aboriginal youth are lower in comparison to their Caucasian peers. Thus, more research is needed to describe and better understand the physical activity behaviors of Aboriginal youth (Willows 2005; Young and Katzmarzyk 2007) in order to halt increasing chronic disease rates among this population. Although efforts have recently been made to improve our understanding of physical activity in the Canadian Aboriginal population (Bryan et al. 2006; Katzmarzyk 2008; Ng et al. 2006; Young and Katzmarzyk 2007), this paucity of data is incongruent with the relatively large volume of information on the health of this population (Young and Katzmarzyk 2007). To address these deficits in the literature, a scientific knowledge base on the physical activity behaviors of Aboriginal youths must be developed.

2.7.2.2 Diet

Healthy eating is defined as "eating practices and behaviors that are consistent with improving, maintaining and/or enhancing health" (Taylor et al. 2005). In Canada, there are evidence-based guidelines for a variety of age and sex groups, similar to those developed for physical activity, to guide food intake (Health Canada 2007). These recommendations have been developed to meet nutrient standards (Dietary Reference Intakes) and to be consistent with evidence linking diet to a reduced risk of chronic diseases. *Canada's Food Guide* describes the types and amounts of foods that should be eaten in four food groups: 1) vegetables and fruit; 2) milk and alternative products; 3) grains; and 4) meat and alternatives (Health Canada 2007). *Canada's Food Guide* also recommends a certain number of daily servings from each of the four food groups and suggests that the consumption of "other foods" be limited (i.e., food items not identified as belonging to the four food groups, such as sweets, candy, oils, soft drinks and condiments).

Given that Aboriginal cultures have different values, traditions and sometimes different food choices from those of the general Canadian population, in 2007, the Public Health Agency of Canada published a new food guide called, *Eating Well with Canada's Food Guide: First Nations, Inuit and Métis*. This new *Food Guide* has been tailored to reflect traditions and food choices of First Nations, Inuit and Métis, and is a complement to the 2007 *Canada's Food Guide*. It shows examples of traditional foods of Aboriginal peoples and explains how traditional foods can be used in combination with store-bought foods for a healthy eating pattern. It also shows pictures of store-bought foods that are generally available in rural and remote locations, and provides unique images and content developed for Aboriginal populations (Health Canada 2007). It is hoped that this new *Food Guide* will be an important tool for Aboriginal individuals, families and communities to learn about and share ways of eating well, including traditional and store-bought foods (Health Canada 2007).

A number of methods are available to assess eating and dietary behaviors. Selection of an appropriate assessment technique is guided by the purpose of the assessment and available resources such as time, personnel, and funds. Information regarding energy intake can be obtained using one of several basic methods, but may be confirmed or expanded using more than one method or a combination of them (Mitchell 1997). All methods are limited by the participants' willingness and ability to accurately report food intake honestly and completely. Most studies adopt simple methods such as a questionnaire, interview, or other subjective assessment methods to assess food intake. The 24-hr dietary recall, a quick and inexpensive method, is described in detail in Chapter 3 and therefore will not be described again here. The food frequency questionnaire (FFQ), which consists of a list of foods and a scale indicating the frequency of the consumption of those foods over a given length of time, is useful when specific food items or nutrient groups, need to be identified (e.g., calcium). Although quick and inexpensive, the FFQ is known to produce estimates of energy intake that are significantly higher than those obtained from 24 hr recalls (Treiber et al. 1990). To gather food intake data from an alternative method called the food record, all foods/beverages consumed, the time of day, amounts consumed, and methods of preparation, must be recorded. Records are kept for 2 – 7 days, with a minimum of three days (Schlundt 1988). A main advantage of this method is that the individual being assessed becomes very aware of their eating behaviors; however, food records require considerable time and effort, and while keeping the record, poor compliance in recording the data and conscious or unconscious changes in eating habits may occur. While all of the above self-reported methods are relatively quick and simple, all have been shown to misrepresent the actual amount of energy consumed (Jebb 1997). While weighed food diaries and direct observation of food intake, on the other hand, may provide a more accurate picture of intake, particularly in children, these techniques are more inconvenient, invasive and labor-intensive. These constraints may also influence reporting and lead to behavioral modification that may alter normal intake patterns. Thus, there is a trade-off between the ease of use and the accuracy of the assessment method, but in many cases, simple methods to assess energy intake may be most appropriate for youth.

Development of new improved techniques to assess energy intake in children has been hindered by the inability to cross-validate instruments with any known standard technique (Goran 1998). However, with the introduction of double-labeled water as a means to check the internal consistency by measuring energy expenditure, several advances have been made. This approach assumes that, for subjects who are in energy balance, energy intake must equal the total energy expenditure measured by doubly labeled water. Using the double-labeled water approach, studies in adults have shown that most food intake methods underestimate actual food intake (Schoeller et al 1990). In children, previous studies with double-labeled water have shown the FFQ overestimates total caloric intake by approximately 50% (Kaskoun et al. 1994), whereas repeated 24 hour recalls (Johnson et al. 1996) and weighed diet records (Livingstone et al. 1992) provide reasonably accurate group mean intake values, although these values are not accurate on an individual basis.

In summary, the accurate gathering food intake data and its careful interpretation is a complex task, particularly in children. The purpose of the study, the study population, financial issues, and the time available for the study are issues that need to be addressed prior to selecting a dietary intake method. In addition to quality control during the energy intake assessment, the training and skill level of the researcher as well as the quality of the nutrient database and analysis software are key requirements for successful analysis.

Relationships of physical activity and diet with adiposity

Like physical activity, diet has been implicated in the current obesity trend, and there is growing evidence to suggest that Canadian youth may be making unhealthy food choices that may lead to obesity and related health problems (Taylor et al. 2005). Although there is much available information from the U.S. in comparison to Canada, available evidence suggests that similar concerns exist in Canadian youth (Taylor et al. 2005), including low fruit and vegetable consumption and high intakes of less healthy foods, such as high fat, high sugar foods like candy, chocolate bars and sugar sweetened soft drinks (Evers et al. 2001; King et al 1999; Shields 2005). Unhealthy eating behaviors in youth are of concern given the possible interference with healthy growth and development, in addition to the development of unhealthy habits that may continue into adulthood (Health Canada 2007). Additionally, increased risk for chronic diseases such as obesity and T2D are an issue (Taylor et al. 2005), particularly in Aboriginal youth, which seem to have a predisposition for developing central adiposity and obesity-related metabolic disorders, such as high cholesterol and hypertension (Ho et al. 2008; Horn et al. 2007). While it has been suggested that the current dietary practices of some Aboriginal peoples in Canada pose significant health risks (Willows 2005), there are many gaps in knowledge pertaining to the eating behaviors, including descriptive data on urban Aboriginals, and First Nations living off-reserve, and children (MacMillan et al. 1996; Young 2003). Given the enormous diversity of Aboriginal people in Canada, it has also been suggested that research to address these gaps take place at the local and national level (Willows 2005). Thus, a range of health promotion strategies is required. However, to design effective interventions, a better understanding of the eating behaviors of Aboriginal children and adolescents is necessary to broaden the limited amount of research in this area within Canada.

In the past, Aboriginal people maintained a hunter-gather lifestyle which involved extracting and processing foods from the land and water by hunting, gathering and fishing. As a result, they subsisted on foods high in protein and low in fat and carbohydrates (Health Canada 1995). However, the contemporary lifestyle today no longer requires hunting and gathering for survival, and traditional foods (defined by Willows (2005) as foods that are culturally accepted and available from local natural resources that constitute the foods systems of Aboriginal peoples) have largely been replaced by market foods which are typically of low diet quality.

Evidence suggests many health problems experienced by Aboriginal peoples today are associated with their diet (Kuhnlein et al. 2004; Receveur and Kuhnlein 1998). For example, anemia, dental caries, obesity, heart disease and diabetes may be related to poor diet. In Aboriginal youth, data regarding eating behaviors are limited, and existing studies included only a few Aboriginal communities across Canada and hence have a narrow geographic focus.

A recent Statistics Canada report (Garriguet 2008) investigated the association between obesity and the eating habits of the Aboriginal population. Findings from the cross sectional analyses using CCHS 2004 data showed that at ages 19 to 30, higher obesity rates in female adults could be explained, in part, by higher caloric intake, despite identical energy needs based on height, weight age and physical activity (Garriguet 2008). In addition, this same report showed that the majority of excess calories taken in came from “other foods” (Garriguet 2008). When comparisons were made between Aboriginal adults and non-Aboriginal Canadians, date showed that like non-Aboriginals, many Aboriginal people did not follow the Canada Food Guide. For example, a high proportion of Aboriginal peoples were not consuming the suggested number of vegetables and fruits, grain or milk products (Garriguet 2008). However, it was also noted that further exploration would be necessary to establish whether these food guide recommendations for the general population would be appropriate for the Aboriginal population.

Other studies on the dietary patterns of North American Aboriginals show that consumption of fruits and vegetables is limited, but consumption of foods high in sugar and fat is high (Giamattei et al. 2003; Gittelsohn et al. 1998; Ludwig et al. 2001). For example, studies with the Pima Indians have estimated the usual diet to consist of 47% carbohydrate, 35% fat, 15% protein, and 3% alcohol (Boyce and Swinburn 1993). Similarly, findings suggest that Aboriginal peoples regularly eat butter, lard, whole milk, fry bread, fried meats and vegetables, and for preparatory purposes, generously use fats (Broussard et al. 1995). Thus, greater overall energy intake is likely the result of a higher proportion of energy from fat and sugar (Ballew et al. 1997; Broussard et al. 1995; Giamattei et al. 2003; Gittelsohn et al. 1998; Ludwig et al. 2001).

Data on the eating habits of Aboriginal youth are generally in agreement with the above findings. In 2000, Story and colleagues reported that Aboriginal youth were more likely to consume more total energy, have a higher intake of total fat, and a lower intake of fresh fruit and vegetables than non-Aboriginal youth. In schoolchildren from Sandy Lake First Nations in Ontario, data from 24 hr recalls showed that their diets were high in fat and simple sugars and low in dietary fiber (Wolever et al. 1997); in addition, intakes vegetables, fruits and milk products were low (Jimenez et al. 2003; Wolever et al. 1997). High fat intakes and low fruit and vegetable intakes have also been observed in Mohawk children (grades 4-6) in the Kahnawake Schools Diabetes Prevention Project (KSDPP) (Trifonopoulos et al 1998; Jimenez et al. 2003). Similarly, infrequent fruit and vegetable consumption and lower fiber intakes were recently reported in young Cree (9-12 years) children (Downs et al. 2008). A small, descriptive pilot study on urban Aboriginal adolescents in Saskatchewan supports these findings, reporting that the average daily consumption of fruit and vegetables was much less than the recommended five servings (Anderson and Chad 2006). Thus, while consumption of energy dense, fatty foods tends to be high in Aboriginal youth, intake of healthy high-fiber, nutrient-rich foods, such as vegetables and fruits, tend to be low.

Aboriginal youth also tend to obtain a high percent of food energy from sugar (Horn et al. 2001), which might also contribute to the higher energy intakes observed in Aboriginal groups (Ballew et al. 1997; Broussard et al. 1995). In 1998, Trifonopoulos and associates reported that sucrose intake in Mohawk children was very high, contributing more than 16% of total energy. While table sugar may be used as an additive to foods common in the Aboriginal culture (e.g., tea), high intakes of sugar in the young Aboriginal population are likely linked to the consumption of soft drinks and sugary sweetened beverages. For example, findings have indicated that the consumption of sweetened soft drinks and beverages in Aboriginal youth is more than twice the national average (Gilbert et al. 1992).

In North America, soft drink consumption has become a highly visible, controversial public health and policy issue. Soft drinks are viewed by some as a major contributor to the obesity epidemic and consequently are being targeted as a means to help curtail the upsurge of obesity (Vartanian 2007). Studies with Caucasian youth have indicated that consumption of sugary sweetened beverages (SSB) (i.e., soft drinks and/or high calorie, sugar sweetened juices or drinks) is positively correlated with adiposity (Gillis and Bar-Or 2003) and a number of medical problems, including T2D (Vartanian 2007). In 2007, a meta-analysis of 88 studies conducted by Vartanian concluded that soft drink intake is associated with increased caloric intake and therefore increased body weight. Similarly, a systematic review by Malik et al. (2006) showed that a greater consumption of sugary sweetened beverages (SSB) was associated with weight gain and obesity. Thus, the relationship between sugar intake, including sugary sweetened beverages and adiposity in Aboriginal youth warrants further investigation.

Another dietary behavior that may be related to healthy body weights, specifically in the Aboriginal population, is the consumption of a traditional diet. A traditional diet contains plant and animal foods harvested from the local environment, such as caribou, whitefish or berries (Receveur and Kuhnlein 1998), which reflect their origin from the land (Wein et al. 1991). The consumption of traditional foods may be inversely related to the consumption of energy-dense, market foods. In Aboriginal youth, for example, market foods which are convenient, but high in fat and sugar, may serve as a replacement for more traditional foods that are an important part of the Aboriginal culture. In 1997, Wolever and colleagues showed that Ojibwa-Cree adolescents (aged 10-19 years) from Northern Ontario ate more potato chips, fried potatoes, hamburger, pizza, soft drinks and table sugar and less traditional foods such as bannock and wild meats than Ojibwa-Cree adults (49 years and older) and had significantly greater intakes of simple sugars and less protein compared to adults.

Traditional foods are considered to be important to the health of Aboriginal peoples for a number of reasons including the direct benefit of the nutritional value of the food itself, the physical activity associated with its procurement, or its role in mediating positive health determinants such as self-efficacy (Receveur and Kuhnlein 1998). Given the association between consumption of traditional foods and greater overall health (Receveur and Kuhnlein 1998; Young et al. 2000), and energy dense market foods and T2D risk (Gittelsohn et al. 1998), traditional food consumption in Aboriginal youth could play a role in the attainment of a health body weight and prevention of obesity. In an effort to recognize the importance of traditional food use and increase cultural awareness, The Public Health Agency of Canada published a new food guide in 2007 titled, *Eating Well with Canada's Food Guide: First Nations, Inuit and Métis* (http://www.hc-sc.gc.ca/fn-an/alt_formats/fnihb-dgspni/pdf/pubs/fnim-pnim/2007_fnim-pnim_food-guide-aliment-eng.pdf).

Willows (2005) suggests that the current dietary behaviors of some Aboriginal groups may pose significant health risk and diminish quality of life. However, since there are few comprehensive studies documenting the eating behaviors and the determinants of healthy eating in Aboriginal communities, it is critical to obtain this information to develop a scientific knowledge base. In view of the enormous diversity of Aboriginal peoples, research to address the gaps should take place at both the national level and a more local, community-based level.

2.8 SUMMARY AND STATEMENT OF THE PROBLEM

Research suggests that Aboriginal youth have a high prevalence of overweight, obesity and adiposity (Hanley et al. 2000; Horn et al. 2001; Raine 2004; Tremblay et al. 2005); however, there are limitations of the data pertaining to Aboriginal youth in Canada. Despite the well known associated bias in data that are not measured, not all studies have measured heights and weights to calculate BMI. Some studies have used parental report, which tends to inflate estimates due to parents under-reporting the height of the child (Shields 2005), while others have used self-report, which typically underestimates overweight prevalence (Strauss 1999). Additionally, past research has emphasized BMI as a surrogate for adiposity, although it is known to have greater error in comparison to other assessment methods (e.g. DXA, ultrasound or QCT) (Goran et al. 1996); furthermore, BMI may not be indicative of high risk central adiposity (Daniels et al. 2000; Janssen et al. 2005). While there is a high prevalence of metabolic-related diseases among Canadian Aboriginal peoples that have been associated with a high waist circumference, assessment of central adiposity in this population has been relatively under studied. Earlier work by Young and Sevenhuysen (1989) indicated that obesity among Northern Canadian First Nation adults was primarily centrally located, and Leslie et al. (2007) showed that Aboriginal women had greater trunk fat accumulation in comparison to Caucasian women, there is a paucity of studies investigating both total and central adiposity in Aboriginal Canadians. Likewise, there is a paucity of research investigating adiposity development in Canadian Aboriginal children and adolescents. While Katzmaryzk and Malina (1998) reported that First Nations peoples (including youth) generally have greater subcutaneous fatness and a more centralized fat distribution than people of European ancestry, their sample was relatively small (i.e., n = 21 + 17 Aboriginal boys and girls, 5-19 years). More recent work that assessed adiposity using measured waist circumference in Cree youth (9-12 years) from Northern Quebec indicated that 62% were considered to have central adiposity. However, it is unclear how these data from studies of Aboriginal youth would compare to their non-Aboriginal peers. Examining relationships between ethnicity, physical activity, diet and adiposity among Canadian Aboriginal youth is therefore an important step for improving our understanding of the health of the Aboriginal population.

2.9 OBJECTIVE, PURPOSES AND HYPOTHESES

To address the aforementioned limitations in the literature, the objective of this research was to study the relationship(s) of ethnicity, physical activity and diet with adiposity development in Aboriginal youth. To meet this objective, three separate studies were undertaken: 1) to comprehensively assess adiposity in Aboriginal and Caucasian youth matched by age, sex and maturity; 2) to assess the role of ethnicity and sex on physical activity (PA) levels and identify the proportion of Aboriginal youth meeting international PA and T.V. viewing recommendations; and 3) to explore relationships of physical activity and diet with adiposity in Aboriginal youth. It was hypothesized that: (i) Aboriginal youth would have greater total and central adiposity than their age, sex and maturity matched Caucasian peers; (ii) Aboriginal youth would have lower physical activity levels than their Caucasian peers and the majority of Aboriginal youth would not meet international PA and T.V. viewing recommendations, and Aboriginal boys would have higher adjusted physical activity energy expenditures than Aboriginal girls; and (iii) that physical activity and diet would be related to adiposity. With these specific purposes and hypotheses in mind, this thesis was designed to investigate the following research questions in three scientific papers.

2.9.1 Research Question 1

Does adiposity development in Aboriginal youth differ from Caucasian youth?

2.9.2 Research Question 2

What role do ethnicity and sex have on physical activity levels and what proportion of Aboriginal youth are meeting physical activity and T.V. recommendations?

2.9.3 Research Question 3

Are physical activity and diet related to adiposity in Aboriginal boys and girls?

3

METHODS

3.1 OVERVIEW OF METHODS

This chapter provides an overview of the methods employed for the three studies included in this thesis. Specific analyses and data collection procedures for each study are described in chapters four through six.

3.2 STUDY DESIGN

Data for the series of studies were collected from an Aboriginal sample of youth using a cross-sectional design. For comparison purposes, data from a Caucasian sample was drawn from the Pediatric Bone Mineral Accrual Study (PBMAS) (Bailey 1997; Bailey et al. 1996; 1999), which used a mixed longitudinal design. Data from the PBMAS were collected repeatedly from participants on various measures, one to three times per year, rendering the study longitudinal; the "mixed" aspect of the longitudinal study is applicable because new participants of various ages were introduced into the study for the initial three years producing a number of different chronological age cohorts (Bailey 1997). However, for the purposes of the present analyses, data from the Caucasian youth was drawn from only one measurement occasion for comparison to Aboriginal youth. Given that the methods for the PBMAS have been detailed elsewhere (Bailey 1997), a brief summary has been included in the following sections, while a detailed account of the methods of data collection for the Aboriginal sample have been described below.

3.3 ETHICAL APPROVAL AND CONSENT

Ethical approval of this research project was obtained from the Human Experimental Behavioral Sciences Ethical Review Committee of the University of Saskatchewan (see Appendix D). The original PBMAS received approval from the University and Hospital Advisory Committee on Ethics in Human Experimentation. All Aboriginal and Caucasian participants provided written assent and written consent was obtained from their parent/guardian(s) at the time of data collection. Written assent and consent forms developed for use with the Aboriginal participants and their parent/guardian(s) can be found in Appendix E and F, respectively. Verbal and/or written consent was also obtained from each Aboriginal school and their respective community leader(s), where applicable, prior to the study.

3.4 PARTICIPANTS

3.4.1 Aboriginal Youth

This research project began in 2004, when a partnership between the University of Saskatchewan and the staff and students of an urban Aboriginal High School (Oskayak High School) was formed to address ongoing issues of health concern in Aboriginal peoples, specifically, obesity and Type 2 Diabetes. Unpublished results (Anderson and Chad 2006) emanating from this pilot study (n =61 Aboriginal youth, 14-20 years), showed that unhealthy lifestyle behaviors were common among the Aboriginal youth attending the school (see Appendix A for summary report) suggesting a need for culturally appropriate healthy lifestyle initiatives (e.g., an after-school physical activity club and cafeteria menu changes). In the interest of extending the aforementioned pilot project to other Aboriginal schools across Saskatchewan, approximately 20 reserve and urban communities or schools (e.g., Kinistin First Nation, Beardy's First Nation, Sakawew High School, Muskeg Lake First Nation, White Buffalo Youth Lodge, Muskoday First Nation School, Caswell School, etc.) that had a high proportion of Aboriginal students were sent a letter introducing the study along with an invitation to contact our research personnel for more information about the project (Appendix B). If interest was expressed after the initial mailings, the main researcher of this study telephoned the school to provide more information about the research study. Posters promoting the project were developed and tailored for each school to display (see Appendix C). Mailings continued until recruitment targets (a minimum of 200 Aboriginal youth, with approximately equal representation of girls and boys 8 through 17 years (i.e., 10 Aboriginal boys +10 Aboriginal girls)) in each of the 10 chronological age cohorts to match the PBMAS sample of Caucasian youth) had been met.

To maximize the chance of successful research, each school was encouraged to collaborate with the University research team to provide input. This included: a) corresponding with the University researchers to discuss the objectives and expectations of the project; b) assisting in promoting the project and recruiting Aboriginal youth to participate; c) assisting with the distribution and collection of assent and consent forms; and d) providing input and feedback before, during and after the project related to the development of the research tools/questionnaires, the coordination and organization of transportation to the University and the selection of activities to be carried out on the day of the project. Each community (or school) was ensured that participation in the project would be provided free of charge and that financial aid would be available to assist with travel costs (e.g., transportation and meals) to the University. Of the 18 schools (13 reserve, 5 urban) that were personally contacted and provided with more information about the study, 100% expressed interest in participating; however, of these, 16 schools (12 reserve and 4 urban) carried out the project to completion for various reasons (administrative/staffing constraints, school scheduling conflicts, poor travel conditions, etc). A liaison at each participating school or community was identified to communicate with the principal investigator of this study.

Although an ongoing process, relationship building with the Aboriginal schools (and/or communities) involved was initiated early in the research process and continued throughout the study. Consequently, the principal researcher of this project participated in several school events and community activities (i.e., smudge ceremonies, Christmas feasts, Pow-wows, health fairs, winter carnivals) to build a rapport with the youth interested in the project and maximize the potential for the success of the project. Although a timely process, engaging the schools and communities allowed the researcher to be enriched by a deeper knowledge of the unique histories and traditions of the Aboriginal culture; moreover, this approach brought the community and university researchers together, so that the knowledge and experiences of everyone involved could be shared. Established relationships with the Aboriginal schools and community partners were therefore instrumental to the feasibility and success of this project.

Three hundred and fifty two participants self-identified as Aboriginal (i.e., being descendants of the original inhabitants of North America, including First Nations, Métis, and Inuit) were recruited into this convenience sample. Among the participants who indicated they were Aboriginal, 85% self-identified as First Nations; 15% were Métis. No youth identified themselves as Inuit. The majority (i.e., 74%) of First Nations respondents further identified themselves as Cree. Given that the school or community liaison was responsible for sending information and consent forms to the youth (8-17 yrs) and that students who were absent on the day their class visited the lab for testing were generally not tested on a subsequent day, the response rate could not be calculated. Data collection took place from January 2005 to December 2006 with 352 Aboriginal youth from 12 rural/reserve and 4 urban schools located in Saskatchewan. However, because data for some variables were incomplete, the number of Aboriginal youth in each of the studies varied.

3.4.2 Caucasian Youth

The Caucasian youth were part of the Saskatchewan Pediatric Bone Mineral Accrual Study (PBMAS) (1991- 1997) (Bailey 1997; Bailey et al. 1996; 1999), which used a mixed-longitudinal design and incorporated eight chronological age cohorts with youth aged 8 through 15 years at study entry (i.e., in 1991). During the six years of data collection, the composition of these clusters remained the same. In 1991, 375 students attending two elementary schools in middle-class neighborhoods in the city of Saskatoon (population approximately 200,000) were provided with consent forms. Of these 375 students, 228 (113 boys and 115 girls) provided written parental consent to be involved in the PBMAS study. From 1992 to 1993, an additional 31 subjects were recruited and scanned. After 6 years of data collection, 109 males and 113 females had been measured on one or more occasions (median 6 occasions). For inclusion in the present analyses, Caucasian participants were matched by age, sex and maturity status (i.e., age from peak height velocity) to our Aboriginal sample of youth to ensure representation in each age and maturity category. Two hundred and four Caucasian youth (107 females and 97 males) fulfilled these requirements and these subjects represent the Caucasian study (i.e., comparison) sample for the present investigation.

3.5 DATA COLLECTION PROCEDURES

Data collection for the Aboriginal and Caucasian samples was conducted in the same lab and followed the same standardized protocols, albeit 10 years apart. Each participant consented to undertake a body composition assessment and a series of questionnaires. Completion of the assessments and questionnaires took place on one occasion, at a time that was convenient for the participants, which was typically during school. Occasionally, data were collected in the evenings or on the weekends to accommodate the participants. In total, the assessments and questionnaires took each participant approximately 45 - 60 minutes to complete. The procedures described below are in reference specifically to the Aboriginal sample, as procedures for the PBMAS have been described in detail elsewhere (Bailey 1997).

All measurement tools (i.e., body composition assessment protocols and questionnaires) were pilot tested for feasibility and comprehension on a group of Aboriginal youth (n = 43). The youth involved in the pilot were asked to identify any questions they found unclear or too cumbersome. Additionally, three teachers were asked for their feedback to help make the questionnaires easier for Aboriginal youth to complete. Minor revisions were then made to the study protocols and questionnaires.

While a few participants attended individually, most youth in this study visited the College of Kinesiology within their larger school/community as part of a special field trip. Given that many of the groups were quite large in number (e.g., >40), the youth were often divided into several smaller sub-groups (comprised of approximately 4-5 youth) to allow for privacy and adequate space to carry out the testing. In addition to the research testing, a number of other health-related activities were planned for the youth throughout the day. This meant that, in addition to the research testing, the youth (and their respective teachers/chaperones) were given opportunities to engage in physical activities and/or classroom activities throughout the day. All activities were chosen and planned by the Aboriginal teachers and the principal researcher prior to the groups' visit to the College. Whenever possible, a university student of Aboriginal ethnicity was hired to coordinate, lead and participate in the research activities with the Aboriginal youth participants. In addition to the opportunity to participate in fun physical activities in the College of Kinesiology, incentives such as lunch and funding for sports equipment were provided as a thank you.

With the exception of the dietary recall, which was administered by a trained researcher using an interview approach, all questionnaires were self-report. With the help of trained research assistants, the principal researcher of this project distributed and administered all questionnaires, giving each participant a brief explanation of the project and the questions before they began. Written instructions, included on the questionnaires, were read aloud for the participants. The researcher remained in the room during completion of the questionnaires at all times and when the need arose (i.e., if the student had difficulty in reading and writing), administered the questionnaires via an interview style format. A researcher was also available to address any questions or concerns regarding either the survey questions or the study, while still allowing each participant the necessary privacy to provide their own responses. When the participant had completed all questionnaires, the researcher quickly perused each survey to ensure that no questions were unintentionally missed before the participant exited the lab.

A core team of researchers assisted the main researcher of this project to carry out all aspects of the testing except for the DXA assessment. Every effort was made to ensure privacy and confidentiality during the anthropometric assessments; therefore this testing was carried out behind an enclosed space that was separate from the other small group of participants being tested concurrently in the lab. Standard procedures performed at the Physical Activity Complex in the College of Kinesiology were followed. Although the principal investigator remained present during the DXA scan assessment, a nuclear medicine technician administered all DXA assessments.

3.6 MEASURES

All measures assessed with the Aboriginal youth and the Caucasian PBMAS samples were identical in this study, unless otherwise stated below.

3.6.1 Body composition

In an ideal setting, pediatric research includes a valid and reliable measure of body such as dual energy x-ray absorptiometry in addition to the usual measures of height and weight. The present study is unique in that it not only measured height, weight, and waist circumference, but also assessed adiposity through dual energy x-ray absorptiometry **(**DXA).

3.5.1.1 Height and weight

Participants wore light indoor clothing with their shoes removed for all height and weight measurements. Height was recorded as a stretch stature to the nearest millimeter using a Harpenden wall stadiometer (Holtain Ltd.). Stretch stature was taken as the maximum distance from the floor to the highest point on the skull (i.e., the vertex of the head) when the head was held in the Frankfort plane (Ross and Marfell-Jones 1991). Participants were asked to stand with their feet together, directly touching the base of the stadiometer, and arms were hanging naturally by the sides. The heels, buttocks, upper back and back of the head were in contact with the stadiometer. The subjects were instructed to look straight ahead and take a breath. The research ensured that the subject’s heels were not elevated and then applied gentle traction alongside the mastoid processes as the subject exhaled. The researcher then brought the headpiece on the stadiometer down so that it was in contact with the vertex of the head. Duplicate measures were taken to within 0.1 cm, and when the difference between the first two measurements exceeded 0.4 cm, a third measurement was taken and the mean of the three was recorded (see Appendix H). Weight was measured using an electronic scale (Tanita Solar model HS-301). The subject was asked to step on the scale and remain as still as possible until a reading was taken. Weight was measured in duplicate to obtain a reading within 0.1 kg. A third measure was taken only if necessary (i.e., if the first two were not within 0.2 kg).

Body mass index (BMI) (BMI = body mass/height^2) was determined from the mean measured weights and heights and calculated to the nearest 0.01 kg·m^{-2} and standards developed by the International Obesity Task Force (Cole et al. 2000) were applied. In accordance with the IOTF Guidelines (Cole et al. 2000), youth were classified as non-overweight if their BMI was less than the 90th percentile; as OW if their BMI was equal to or exceeded the 90th percentile, and as "OB" if their BMI was equal to or above the 97th percentile (Cole et al. 2000). Although absolute measures of BMI have been used in the past as a surrogate for adiposity, this study also used BMI z-score, a relative measure adjusted for age (i.e., the number of standard deviation units a child's BMI is away from the mean or reference value). BMI z-scores in this study were computed with reference to sex and age specific mean BMI values and distributions using mean values from all youth in this study.

3.6.1.2 Waist circumference (WC)

Waist circumference (WC) was measured while the participant stood upright, with both feet together and arms hanging freely at their sides. The measurement was taken directly on the skin with a flexible steel tape, at the level of the narrowest point between the lower costal border and the iliac crest, at the end of a gentle expiration. When the point of natural narrowing could not be determined, the circumference was measured midway between the two landmarks (Norton et al. 1996). If the participant did not feel comfortable having the measurement taken directly on the skin, then it was taken over top of light clothing, and this adjustment of technique was noted. Two measurements were taken to the nearest 0.1cm, with a third if the first two measurements were not within 0.2 cm; the mean of these measurements was recorded (see Appendix H).

Waist circumference is considered to be an index of obesity-related health risk for children and adolescents (Daniels et al. 2000; Katzmarzyk 2004) and can be used to express central adiposity (Brambilla et al. 2006; McCarthy et al. 2003). Using the Third National Health and Nutrition Examination Survey (NHANES III) reference data, participants who had a measured waist circumference that met or exceeded the 85th percentile of sex and age-matched youth were considered to have central adiposity. NHANES III measurements for WC were performed at the uppermost lateral border of the right iliac crest, which is generally comparable to the site of measurement used in this study (Wang et al. 2003).

3.6.1.3 Dual energy x-ray absorptiometry (DXA)

To obtain body composition measures, the participants were scanned by dual energy x-ray absorptiometry (DXA). The DXA total body scan is a quick, precise, non-invasive method of assessing total body and regional body composition of bone mineral, fat and lean tissue mass. Several studies have demonstrated its validity (Pintauro et al. 1996; Svendson et al. 1993) and reliability (Gutin et al. 1996; Morrison et al. 1994) and it has been proven useful for assessing body composition in the pediatric population. Although DXA involves radiation exposure, it is extremely low (0.015 mGy) (Hologic Discovery Operators Manual 2002). More details regarding the DXA technique can be found in Chapter Two.

The technical aspects of scanning procedures remained consistent with previous work in our lab (Bailey 1997; Thompson et al. 2003) and standardized procedures in the College of Kinesiology were followed (outlined below). Further, the same group of technicians who did our previous PBMAS scans in the research lab continued to work with us in this study. While special pediatric software was not used in this study for youth with a lower body weight, all scans were manually corrected by the Nuclear Medicine Technician. Daily calibration of the machine was executed with the lumbar spine phantom, the step phantom and a whole body uniformity scan. A single Nuclear Medicine Technician performed all measurements and software analyses for data collected from the Aboriginal youth.

All participants in the present study were encouraged to undertake a DXA scan before or after they completed their questionnaires. However, any youth who did not feel comfortable participating in the scan were given the option to refrain from this component of the testing. Participants wore plain, loose fitting shorts and a t-shirt, with all metal objects (jewelry, belts, glasses, etc.), socks and footwear removed before the scan to follow appropriate procedures. Prior to the scan, a DXA bone densitometry requisition form (Appendix G) was completed and the subject's name, sex, birthdate, height and weight were entered into the Hologic system file (shown in Figure 3). Subjects were forewarned of the risk of radiation exposure to the fetus, should they be pregnant, prior to the commencement of the scanning procedure.

DXA Overview

While every effort was made to maintain consistency between the procedure used for our Aboriginal study and for the PBMAS, the PBMAS scans were typically conducted annually in October or November, while scans occurred throughout the year for Aboriginal youth. In addition, the PBMAS scans were performed on a Hologic 2000 QDR (Hologic, Waltham, MA) in the array mode, using enhanced global software (7.10.) and analyzed using software version (5.67A) (Bailey 1997). However, total body scans for Aboriginal were performed using DXA technology (Hologic Discovery 4500 *Wi*; Waltham, Mass.) in the R.J.D. Williams Laboratory, College of Kinesiology. For purposes of comparability, repeated measures taken from six subjects were performed on the Hologic 2000 QDR and the Hologic Discovery 4500 Wi consecutively and regression equations were developed to predict values from the newer DXA technology (i.e., Hologic Discovery 4500 Wi). Prediction equations 3.1 and 3.2 below are for total body fat mass percentage and trunk fat mass percentage, respectively.

Figure 2. DXA Regression Prediction Equations

Total Body Fatness (%):

$$y = mx + b \qquad (3.1)$$
$$y = 0.87(x) - .04$$

Trunk Fatness (%):

$$y = mx + b \qquad (3.2)$$
$$y = 0.91(x) + 2.1$$

Where:
y = percentage predicted (total body and trunk fat, consecutively) for Hologic Discovery 4500
m = slope of the regression line
x = percentage obtained from Hologic 2000 QDR (total body and trunk fat, consecutively)
b = value of unstandardized beta coefficient

Each DXA session involved the participant lying still in a supine position, which took approximately 7 minutes to complete. The Hologic Discovery 4500 *Wi* uses an x-ray generator with the x-ray source mounted beneath the participant that is pulsed alternately at low and high energy voltages. The fine collimation aperture used by the DXA system allows high resolution images, improved bone edge detection, short scanning times, and lower patient exposure (~0.015 mGy). The tightly collimated x-ray beam, generated from a tube under the table portion of the C-arm, filters through a rapidly rotation calibration wheel prior to passing through the research participant. The calibration wheel is composed of alternation radiopaque segments with densities equivalent to that of tissue, bone and air. The x-ray photons, having passed through the subject and the calibration wheel, are picked up by a crystal detector located in the portion of the C-arm above the table. At each pixel, the energy photon signals passing through the subject are compared to known bone and tissue values derived from the calibration wheel. This information is received and interpreted by the detector which converts it into an electric current and, eventually, via the system software, into a computer image. An Automatic Internal Reference System is the unique feature of the Hologic instrument and adjusts for temperature change, power or tube flux and provides the DXA machine with a method of pixel-by-pixel calibration in each detector channel. Energy voltages are pre-selected for their ability to maximize separation between bone and soft tissue.

Scan Acquisition Protocol

To collect total body data, the table is first centered with respect to the base to ensure stability and the C-arm is moved out of the way to allow the subject comfortable access to the table. The body is centered and straightened along the midline within the solid longitudinal, whole body lines outlined on the scan mat. The head is positioned so that the first scan line is in the air and no more than six scan lines below the lateral line are marked on the head end of the mat. The chin is raised and the shoulders are depressed by applying gentle traction to the arms. This prevents the overlap of the mandible and the superior aspect of the scapula on the scan image. For tall subjects, the feet are dorsi-flexed during scanning of the lower extremities. The subjects are requested to bend their knees slightly if ankle flexion fails to accommodate the entire skeleton. The hands are placed prone and equidistant from the torso on either side of, but not touching, the body. Participants with a larger body size are asked to tuck the thumbs slightly beneath the soft tissue of the thigh to accommodate both elbows within the scan zone. The feet are internally rotated with the big toes touching to maximize femoral neck display during analysis. The feet are taped in this position to immobilize this region and to provide a standardized position for repeat measures. The soft tissue calibration wedge (Step Phantom) is positioned approximately 2 inches from the right side of the subject at the lower leg. The step of maximum density is positioned toward the subject's head within the scan zone but without touching any portion of the subject. The tissue bar (Step Phantom) must be included within the global **ROI** for analysis of soft tissue to be obtained. All of the tissue bar must be scanned regardless of the size of the participant and a space (at least 2 cm) between the tissue bar and the participant is essential to allow edge detection of the phantom. Any clothing or bedding should be tucked under the participant and away from the Step Phantom. In the event that the Step Phantom touches the subject and automatic definition of the step wedge by the system is not possible, pressing **<Alt t>** will allow manual definition of the tissue bar. When the Step Phantom is located, the system highlights the wedge with a red border which should include all six steps of the phantom but no part of the participant. The size of the tissue box can be adjusted in point **(<*>)** mode if necessary. The yellow subregion lines of the total body image may overlap the tissue bar without interfering with the analysis. Enhanced array total body scans are acquired using a skewed swath technique which is a scan pattern at a 45 degree angle to the array orientation which reduces fan beam parallax. The total body scan requires less than 7 minutes to completion.

Scan Analysis Protocol

All analysis procedures were completed as outlined in the Hologic Discovery QDR Operator's Manual and User's Guide (Hologic Inc., Waltham, MA., 2002). Supplementary notes are provided as an adjunct to the manual procedures.

Several non-diagnostic values are displayed above every scan image. The abbreviation **d0** refers to the attenuation of the beam within the bone segment of the calibration wheel and is a function of the thickness of the tissue through which the beam passes. A **d0** of less than 90 represents an abundance of overlying tissue and a less precise bone measurement as a result. **k** is the ratio of attenuation of tissue in both the low and high energy beam and is usually about 1.20.

The coefficient of variation (CV) for the bone mineral density for all the regions included in the analysis is indicated on the report beneath the subject biography.

Total Body

Enhanced array total body software was used for analysis of the total body scan. The total body procedure consists of the following steps:

1. Image adjustment
2. Region of interest selection
3. Generation of a report

1. Image adjustment

The resolution and contrast are adjusted to allow clear differentiation of the skeletal regions and to identify the differences between bone and soft tissue. This adjustment is similar for all scan analyses and is specific to the image on the display monitor following scan acquisition.

2. *Region of interest selection*

The system software allows for the repositioning of an active line that defines each of the ten specific subregions of the total body. These subregions are defined by the placement of the cut lines on the scan image and are standardized as closely as possible between subjects. When the image appears on the monitor the **<ALT Z>** command is used to adjust the magnified, right hand image to display either the upper or lower portion of the skeleton depending on the region being analyzed. The line is yellow when active and the ten subregions of interest are defined as follows:

a. Head: the horizontal line above the shoulders is adjusted to immediately below the mandible.

- *The head region is defined superiorly and laterally by the borders of the global ROI and inferiorly by the shoulder line.*

b-c. Arms (L and R): the vertical lines at the shoulder joint are angled through the joint space between the glenoid fossa of the scapula and the head of the humerus. This line should differentiate the soft tissue of the trunk from that of the arm regions. If the arms are too close to the torso as in a large subject, this is not always possible and some overlap occurs between tissue regions. The image adjust function is used to highlight the soft tissue image and the lines repositioned to maximize the amount of soft tissue included in each region.

- *The arm regions (L arm, R arm) are defined superiorly by the horizontal shoulder line, medially by the vertical arm line bisecting the glenoid fossa and laterally by the border of the global ROI.*

d-e. Spine [Thoracic (T) and Lumbar (L)]: the vertical lines on either side of the spine are moved close to but not touching the vertebral bodies. These lines should be *bent* to match the curvature of the spine as closely as possible. This is accomplished with the cursor in active point (blue) mode which is enabled with the <*> key. The <INS> key will add additional points to the line if more precise contouring is required. The small, transverse line is positioned at the T12-L1 interspace.

- *The thoracic spine region (T spine) is defined superiorly by the horizontal shoulder line, laterally by the two vertical spine lines and inferiorly by the short transverse line at T12-L1.*
- *The lumbar spine (L spine) region is defined superiorly by the small transverse line at T12-L1, laterally by the vertical spine lines and inferiorly by the line at the iliac crest.*

f. Pelvis: the horizontal line that marks the superior border of the pelvic region is placed immediately above the crest of the ilium. This line is extended laterally to maximize the amount of soft tissue included in the chest and pelvic regions. It is important that soft tissue in the region of the arm not be included with the soft tissue from the chest region if at all possible. This problem is minimized by careful positioning of the subject with the arms slightly abducted from the torso during scan acquisition. The horizontal, iliac crest line determines the angle at which the oblique segment lines bisect the neck of the femur to describe the lateral border of the pelvic region. This oblique line is directed medially and should bisect the neck of the femur at its anatomical midpoint. This requires point mode to move the point at the inferior tip of the triangle that describes the pelvis down as far as is necessary within the soft tissue area between the legs. The bony, femoral neck, landmark is always maintained at the expense of the soft tissue if necessary.

• *The region of the pelvis is defined superiorly by the horizontal line at the iliac crest and laterally and inferiorly by the oblique lines passing through the center of the femoral neck.*

g-h. Ribs (L and R):

• *The region of the ribs (L Ribs, R Ribs) is defined superiorly by the shoulder line, laterally by the vertical arms lines, medially by the vertical spine lines and inferiorly by the line at the iliac crest.*

i-j. Legs (L and R): the vertical line extending downward from the lowermost point of the pelvic region is positioned between the feet. The vertical lines on the lateral aspects of the legs are extended laterally to include as much of the soft tissue of the thigh as possible. The position of this line is most often limited by the bony hand which should not be included in the soft tissue leg region. The vertical leg line may extend into the tissue bar image without affecting the analyses.

• *The leg regions (L Leg, R Leg) are defined by the oblique femoral line superomedially, by the vertical leg line inferomedially and laterally by the vertical line on the lateral aspect of the leg.*

3. Report Generation

The total body scan data is processed and valued for Area (cm^2), BMD (g), and BMD (g/cm^2) and then calculated and reported for each region and for the entire skeleton (TOTAL). The regional report of the total body includes head, arms (R and L), ribs (R and L), thoracic and lumbar spine, pelvis and legs (R and L). In large subjects, it is sometimes impossible to include all of the soft tissue in some regions without compromising the bony skeleton. The compare function is completed by pressing the >print screen< key once the calculated values and the total body image appear on the monitor.

Total body fat mass was quantified and expressed as a percentage of total body mass. Abdominal fat mass was also quantified; however, the automated software used to quantify the abdominal fat mass also included the thoracic vertebral column and therefore could be a potential source of error. However, the alternative was to manually draw the regions of interest, a procedure that is operator dependent and could therefore also introduce error.

A sample DXA summary report for a total body scan is shown in Figure 3. Although not utilized in this study, Hologic system software provides a reference database to which bone densitometry results can be compared; thus, Z and T score comparisons to same age and sex reference samples (for bone mineral density, which is not applicable to this study) are distributed.

Figure 3 DXA Summary Report for Total Body (Soft Tissue included)

University of Saskatchewan, College Of Kinesiology

87 Campus Drive
Saskatoon, SK S7N 5B2

Telephone: [redacted]

Name: [redacted]	Sex: Female	Height: 143.8 cm
Patient ID:	Ethnicity:	Weight: 38.3 kg
DOB: January 19, 1995		Age: 11

Scan Information:

Scan Date: February 27, 2006 ID: A02270605
Scan Type: a Whole Body
Analysis: February 27, 2006 10:46 Version 12.3
Auto Whole Body
Operator: kds
Model: Discovery W (S/N 80964)
Comment:

DXA Results Summary:

Region	BMC (g)	Fat (g)	Lean (g)	Lean+BMC (g)	Total Mass (g)	% Fat
L Arm	57.14	439.8	1460.9	1518.1	1957.8	22.5
R Arm	64.54	433.7	1539.6	1604.1	2037.9	21.3
Trunk	287.08	3859.6	13383.1	13670.1	17529.8	22.0
L Leg	190.07	2070.3	4770.7	4960.7	7031.1	29.4
R Leg	189.60	1919.3	4689.2	4878.8	6798.1	28.2
Subtotal	788.42	8722.8	25843.5	26631.9	35354.7	24.7
Head	291.57	756.4	2934.3	3225.9	3982.3	19.0
Total	**1080.00**	**9479.2**	**28777.8**	**29857.8**	**39337.0**	**24.1**

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3.6.2 Biological Maturity

3.6.2.1 Sitting height

Sitting height was taken as a measure of stretched sitting stature using a sitting stadiometer (Karrimeter, Raven Equipment Ltd.). The subject sat tall on an elevated surface (i.e., a standardized box) with their upper back and back of the head directly touching the base of the stadiometer. The seated subject was instructed to sit up as much as possible while gentle traction was applied to the mandible. The participants head pushed up the arm of the stadiometer so as to maximize the distance from the vertex to the base of the sitting surface without contracting the muscles of the buttocks and thighs. The researcher then took the reading to the nearest 0.1 cm. Two measurements were taken within 0.2 cm; when the difference between the first and second measurements exceeded 0.2 cm, a third measurement was taken and the mean of the three was recorded (see Appendix H).

3.6.2.2 Leg length

Leg length was calculated by subtracting sitting height from standing height.

3.6.2.3 Chronological age

Each participant recorded their birth date on the DXA scan requisition form (Appendix G) and this information was used to express chronological age in decimal years (see Figure 4). Chronological age (yr) was determined to decimal age value by subtracting birthdate from the assessment date. Data were then truncated using 1 year intervals (e.g., whereby the 15-year age group included data between 14.5 and 15.49 years).

3.6.2.4 Biological age (Years from Age at Peak Height Velocity)

The assessment of biological maturity is important to include in health related studies to control for the effects of normal growth and maturation on outcome variables such as adiposity or physical activity. Age at peak height velocity (APHV) is an index of somatic maturity (Mirwald et al. 2002). Biological age was expressed in relation to years from age at peak height velocity (APHV). For example, a biological age of +2.5 would represent two years and six months past age of peak height velocity. To predict biological age (i.e., age from peak height velocity), sex-specific regression equations incorporating chronological age, body mass and segmental growth characteristics (i.e., sitting height and leg length) were employed (Mirwald et al. 2002) (see Figure 4). Thus, measured sitting height was used to predict age at peak height velocity (APHV), and biological age was determined by subtracting the chronological age of the individual at the time of measurement from the APHV. A continuous measure for biological age was generated and then truncated using 1-year intervals, for example, the -1 year from APHV group included observations between -1.49 and -0.50 years from APHV. Prediction equations 3.3 and 3.4 are for boys and girls respectively.

Figure 4. Biological Age Equations (Mirwald et al. 2002)

♂ *Boys:* *(3.3)*
= -9.236 + [0.0002708 x Leg Length (cm) x Sitting Height (cm)] + [–0.001663 x Age (decimal years) x Leg Length] + [0.007216 x Age x Sitting Height] + [0.02292 x (Body Mass (kg)/Standing Height (cm)) x 100]

♀ *Girls:* *(3.4)*
= -9.376 + [0.0001882 x Leg Length (cm) x Sitting Height (cm)] + [0.0022 x Age (decimal years) x Leg Length] + [0.005841 x Age x Sitting Height] + [–0.002658 x Age x Body Mass (kg)] + [0.07693 x (Body Mass (kg)/Standing Height (cm)) x 100]

Where:
Age (decimal years) = [(Test Date - Birthdate)/365.25]
Leg Length = [Standing Height (cm) – Sitting Height (cm)]
Sitting Height = direct measurement in cm
Body Mass = direct measurement in kg

3.6.3 Physical Activity

Assessment of physical activity was conducted using three self-reports: 1) the Physical Activity Questionnaire for Older Children (PAQ-C) or the Physical Activity Questionnaire for Adolescents (PAQ-A) (Appendix I); 2) the Modifiable Activity Questionnaire for Adolescents (MAQ-A) (see Appendix J); and 3) self-reported screen time questions that asked about time spent watching television or DVDS, playing video games, and using the internet, on both weekdays and weekends (Appendix J). The researcher provided standardized instructions and prompts as the participants worked through the questionnaire, and if questions arose, was available to assist the students in recording their activities.

This combination of self-reported questionnaires was used to assess physical activity behaviors for two reasons. First, physical activity data from Caucasian youth of the same age was previously collected using the PAQ-C/PAQ-A, and this data was used for comparison purposes. Second, the PAQ-C/PAQ-A was used to characterize the general activity habits and provide a general measure of typical physical activity of the youth in this study. However, because it does not allow for estimations of frequency, intensity or duration and resulting energy expenditure (expressed in kilocalories per kilogram of body weight per day), the MAQ-A was required to determine overall energy expenditure, a common outcome measure in any physical activity studies (Marshall and Welk 2008), and calculate the proportion of youth meeting international criterions for optimal health, growth and development. Furthermore, since the MAQ-A was developed for ethnic populations, we deemed it useful for the purposes of our study.

3.6.3.1 The Physical Activity Questionnaire for Children/Adolescents (PAQ-C/PAQ-A)

The Physical Activity Questionnaire for Children (PAQ-C) and the Physical Activity Questionnaire for Adolescents (PAQ-A) are self-report methods used to assess general levels of physical activity in children (aged 4 to 8) and adolescents (aged 9 through 15), respectively (Crocker et al. 1997). Both questionnaires consist of an activity checklist and several questions regarding physical activity during segments of the day (e.g. lunch hour or after school), as well as physical activity on the weekend (APPENDIX I). The main difference between the two is that the PAQ-A includes questions that ask about recess physical activity. Both are self-reported 7-day activity recalls scored on a 5-point scale, with higher numbers indicating higher physical activity levels. The first item is an activity checklist consisting of common sports, leisure activities, and games, with extra space to list other activities. Six items assess physical activity in physical education classes, lunch, recess, after school, in the evenings and on the weekend (with the exception of the PAQ-A, which only includes five items, as it omits the question about physical activity during recess). The next item asks the individual, "Which one of the following describes you best for the last 7 days?" The individual has a choice of five statements describing low to very high activity levels. The last item asks the individual the frequency of his/her physical activity. These nine (or eight in the case of the PAQ-A) items are then used to calculate a final summary activity score (Crocker et al. 1997), determined by tallying the sum of all items and dividing by the total number of question items (i.e., 9 for the PAQ-C and 8 for the PAQ-A), to get an average overall score. The final summary score values range from 1 (low) to 5 (high). The final outcome score ranges from one to five, with a score of five indicating the highest physical activity level. In addition, one item at the end of the questionnaire assesses whether sickness or anything else prevented them from being active in the last week.

Self-reports are the most widely used method to obtain physical activity data since they are relatively quick, easy to obtain, inexpensive, unobtrusive, and non-reactive (Baranowski 1988). The PAQ-C and PAQ-A are cost-effective and convenient self-report method to assess students' physical activity (Crocker et al. 1997). They take from 10 to 20 minutes to complete, making them appropriate for this relatively large study. The PAQ-C has acceptable test-retest reliability (r= .75 to .82) (Crocker et al. 1997) and validity (Kowalski et al. 1997). Convergent validity is supported in the PAQ-C since the PAQ-C is related to the PAR activity rating (r= .73), the PAR 7 - day recall interview (r = .59), and the Leisure Time Exercise Questionnaire (r = .57) (Kowalski et al. 1997).

3.6.3.2 The Modifiable Activity Questionnaire for Adolescents (MAQ-A)

Physical activity patterns were assessed using the Modifiable Activity Questionnaire for Adolescents (MAQ-A) (Aaron et al. 1995; Kriska and Caspersen 1997), a questionnaire developed to assess physical activity behavior in ethnic populations (Kriska et al. 1990). This instrument has been shown to be a reliable and valid measure of self-reported physical activity suitable for use in young people (Aaron et al. 1995) and has been used in previous Canadian Aboriginal studies (Hanley et al. 2000; Kriska et al. 2003). The MAQ-A is designed for easy modification to maximize its feasibility and appropriateness in a variety of minority populations (Kriska 2000). Given the evidence to suggest that the physical activity preferences of young Aboriginals have moved away from traditional activities to more sport and lifestyle activities (e.g., baseball) (Coble and Rhodes 2006), we included a variety of leisure and sport culturally appropriate activities and games common in Aboriginal communities (APPENDIX J). Additionally, we modified the questionnaire to: 1) assess past month rather than past year physical activity in order to reduce errors due to memory recall; and 2) provide a comprehensive menu of activities for organized and non-organized physical activity. These modifications were made to the questionnaire based on previous research in our lab with a larger sample of Aboriginal and Caucasian youth (Spink et. al. 2005).

Participants identified all organized and non-organized leisure activities done over the past 4 weeks as light, moderate, or vigorous intensity. Given that the terms "leisure" and "intensity" may be open to interpretation in different cultural perspectives, the MAQ-A was carefully administered by trained members of our research team. For each activity listed on the MAQ-A, the product of the metabolic cost (METs), average duration in minutes, and frequency for the week was calculated, and then divided by the number of days in the week. The value of each activity (for both organized and non-organized activities) was summed to yield a total KKD (kcal/kg/day) value for each participant. The primary outcome was therefore energy expenditure (Spink et al. 2005). Data were then used to derive three physical activity categories (i.e., sedentary: < 3 KKD, under active: 3 to 6 KKD, and active: ≥ 8 KKD) according to international recommendations associated with healthy growth and development (i.e., ≥ 8 KKD) (Craig et al. 1999). For the purposes of statistical analyses, data were dichotomized into two physical activity groups representing high and low physical activity levels using a cut-point of 8KKD. This cut-point has previously been used in the literature and was chosen based on international recommendations associated with optimal health benefits and growth and development (Craig et al. 1999).

3.6.3.3 Sedentary Time Questions

A commonly used outcome measure for assessing physical inactivity in the literature is time spent engaging in screen time activities. In this study, a self-report checklist was used to assess time spent being sedentary including: 1) watching television; 2) watching DVDS/videos;

and 3) playing video or computer games (APPENDIX J), on both weekdays and weekends. While the use of these questions made it possible to estimate total time spent in sedentary behavior, it is recommended in the literature that individual behaviors not be summed (e.g., T.V. viewing plus time spent playing computer games) since youth typically engage in multiple sedentary behaviors simultaneously (Marshall and Welk 2008). Therefore, for the purposes of our analyses, data from one question relating to time spent watching television was used (where a higher score was indicative of greater viewing time). These data were dichotomized using a cut-point of 2hr/day, as per commonly cited recommendations (American Academy of Pediatrics 2007). Although these T.V. time questions were not validated in the present study, they have been successfully used in our lab previously with Aboriginal and Caucasian youth (Spink et al 2005).

3.6.4 Diet and Eating Behaviors

3.6.4.1 The 24 hour dietary recall

Dietary behaviors were assessed using 24-hour dietary recalls (Appendix K); the most commonly used valid method to assess actual food intakes at a group level (Goran 1998; Johnson et al. 1996). Carrying out a 24-hour recall involves asking the individual the types and amounts of food and beverages he/she consumed the day prior and therefore should not affect the individual's intake. In youth, studies with doubly-labeled water have shown that 24 hour recalls provide reasonably accurate group mean values for intake (Johnson et al. 1996) and are as reliable as a weighed intake or diary approach- both of which are much more burdensome for the participant (Dzioba 1998). Thus, the technique is quick, relatively easy to administer, does not require long-term recall memory or literacy and has low subject burden (McQuaid Cox 1990), all of which are important factors to consider. In addition, 24-hr recalls have been shown to be a valid method for assessing dietary intake among Aboriginal youth (Weber et al. 2004), including Saskatchewan Aboriginal youth (Dzioba 1998; Whiting and Shrestha 1993).

Energy intake was estimated with semi-structured 24-hour dietary recalls using a multiple-pass interview technique with three stages: 1) a quick listing of food consumed; 2) a more detailed description of the specific food items; and 3) a review of the information (Goran 1998). Plastic 3-D food models, measuring cups and spoons were used to determine portion sizes and increase the accuracy of the data. Findings suggest that there is a rapid increase in the ability of children to self-report food intake from the age of 8 years onwards (Livingstone and Robson 2000) and reported energy intake using a multiple pass approach with 24-hr dietary recalls has compared well with total energy expenditure in youth (Goran 1998).

Data obtained from the 24-hour recalls was analyzed for energy and nutrient content using Food Processor SQL for Window (Food Processor SQL, version 8.5, ESHA Research, 2001, Oregon). This program enables the use of both the USDA Handbook 8 (USDA, 1999) and the Canadian Nutrient File (Health Canada 2005) and its' database includes more than 20,000 food items, including ethnic, specialty and fast foods. Food items can be entered from recipes and analyses can include more than 130 nutrients and nutrient factors. Each recall day was entered separately, and an average of all recall days for each subject was calculated.

Using the 2007 Canada Food Guide, the number of daily servings for each of the main food groups was estimated from the recall data and classified according to the age and sex specific food guide requirements (Health Canada 2007). Beverage intake was also assessed by classifying all intakes into two main categories: 1) sugar sweetened beverages (SSB) which included carbonated soft drinks (caloric only), noncarbonated sweet drinks (e.g. Powerade sport drinks and fast food milkshakes) and sweetened fruit juice that was not 100% real fruit juice; and 2) fluid milks (including milk and chocolate milks), which were not classified as SSB. Coffee and teas were not included in either category unless table sugar was added. The 2007 Canada Food Guide was used to determine the number of daily servings of SSB (i.e., for most beverages, a serving is considered to be 250 ml). To estimate the number of servings of "other" foods, data were examined directly from the recalls to search for any foods considered to fall outside any of the four main food groups (i.e., FV, M/A, Meat/A, and Grains) such as foods high in oils and fats, or sweet foods high in sugar. This category also included condiments or sauces such as gravy. Any beverage that was labeled as SSB was excluded from the "other" category. Traditional foods such as caribou, whitefish or berries, defined as part of a diet containing plant and animal foods harvested from the local environment (Receveur and Kuhnlein 1998) and reflecting their origin from the land (Wein et al.1991) were also tabulated directly from the recall data. Each traditional food was only counted once throughout the day, regardless of the serving size or frequency of which it was consumed (Kuhnlein et al. 2004). When all serving size and nutrient analyses were completed, the data were entered into the Statistical package for the Social Sciences (SPSS, version 16.0, Chicago, IL) for further analyses.

3.6.5 Demographics

3.6.5.1 Health and Demographic Questionnaire

Ethnicity was self-identified and was based on responses to a question that provided three different ethnic categories (i.e., First Nations, Métis and Inuit). Additionally, one question asked participants to identify their tribal group (e.g., Cree, Mohawk, Ojibwa, etc.). Assistance from the parent or teacher accompanying the youth was provided if he/she could not respond to this question on their own. To obtain socio-demographic information such as sex and date of birth, a short survey (Appendix L) was also administered to each participant by a trained researcher involved in this study. Geographic location was derived using the participants' current residence as a proxy for classification as urban, rural or reserve using the *Statistics Canada Census Dictionary (2002)*. An "urban" area was therefore considered one that had a minimum population concentration of 1,000 persons and a population density of at least 400 persons per square kilometer, based on the current census population count. Furthermore, the urban population included all population living in the urban cores (population of at least 10, 000 persons), secondary urban cores and urban fringes of census metropolitan areas (CMAs) and census agglomerations (CAs), as well as the population living in urban areas outside CMAs and CAs. "Rural" areas were defined as all territory lying outside urban areas, including any population living in the rural fringes of census metropolitan areas (CMAs) and census agglomerations (CAs), as well as population living in rural areas outside CMAs and CAs. For the purposes of this study, data were coded as urban, rural or reserve, but given that all youth attending reserve schools were located in rural areas, hereinafter referred to as "reserve" in this study.

4

Paper I: Assessment of total and central adiposity in Canadian Aboriginal youth

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Abstract

Objective: Although Aboriginal youth seem to be more susceptible to developing obesity and metabolic disorders than other ethnic groups in Canada, few studies have examined adiposity comprehensively in this population. The purpose of this study was to assess total and central adiposity in Canadian Aboriginal and Caucasian youth matched by age, sex and maturity. *Methods*: 212 Aboriginal and 204 Caucasian youth (8-17 years) were recruited. Heights, weights and waist circumferences were measured and classified using international standards. Dual energy x-ray absorptiometry (DXA) indicated relative total body and trunk fatness. Age of peak height velocity was predicted from somatic growth. Descriptives with independent t-tests and Chi-square analyses were run to detect ethnic differences. ANCOVA was used to assess differences in total body and trunk fatness (covariates height, chronological age and biological age) in girls and boys separately. *Results*: Overweight/obesity and central adiposity were more prevalent in Aboriginal youth compared to Caucasian youth ($p<0.05$). Ethnic differences in total body and trunk fatness were also significant, with Aboriginal girls and boys presenting, on average, 5.4% and 6.0% more total body fatness and 7.6% and 8.3% more trunk fatness, than Caucasian girls and boys, respectively ($p<0.01$). *Conclusion*: Canadian Aboriginal youth have greater prevalence of overweight/obesity and central adiposity, and higher relative total body fatness and trunk fatness than their Caucasian peers, which may predispose them to cardiovascular and metabolic disorders at a very young age. Longitudinal research is needed to confirm the associated health risks in this population.

Key words: *Aboriginal, Canadian, central adiposity, youth, ethnicity, obesity*

Introduction

Evidence suggests that the prevalence of obesity varies by ethnicity (Tremblay et al 2005). Aboriginals (First Nations, Métis and Inuit), in particular, have higher obesity rates and have experienced the most substantial rise in obesity, in comparison to other ethnic groups, over the past few decades (Anand et al. 2001). This increase in obesity has coincided with an increased susceptibility for metabolic disorders (Green et al 2003; Horn et al 2007), even in very young Aboriginal children (Dean 1998; Young et al. 2000). In 2000, a Canadian study showed nearly two-thirds of Aboriginal boys and girls had body mass indexes (BMI) exceeding the 85th percentile for age and a corresponding increased risk for T2D or impaired fasting glucose (Young et al. 2000). While this and other reports suggest that Canadian Aboriginal youth are at high risk of developing obesity and related metabolic abnormalities (Dean 1998; Hanley et al. 2000; Katzmarzyk 2008; Potvin et al. 1999; Young et al. 2000), this proposition has largely been made through the use of BMI, despite evidence to suggest that measures of central adiposity also predict health risk in Aboriginal populations (Connelly et al. 2003; Wang and Hoy 2004). Waist circumference (WC), for example, can be superior to BMI for predicting health risks, whether used alone or in combination (Daniels et al. 2000; Janssen et al. 2005; Maffeis et al. 2003; Savva et al. 2000; Yusuf et al. 2005). Youth with excess body weight and a high WC, for example, have been found to be twice as likely to have high triglycerides, high insulin levels and metabolic syndrome (MetS) compared to youth with excess weight and a low WC (Janssen et al. 2005). While recognizing that overall obesity without central adiposity can also be predictive of adverse health outcomes, a more comprehensive approach to assessing adiposity and related health risk in Aboriginals would therefore be worthwhile.

In Aboriginal populations, there appears to be an underlying predisposition for developing central adiposity (Katzmarzyk and Malina 1998; Leslie et al. 2007; Young 1996). Studies with adults have indicated that Aboriginals have a greater tendency to accumulate adiposity in the trunk in comparison to Caucasians (Katzmarzyk and Malina 1998; Leslie et al. 2007), yet few studies have assessed measures of overall and central adiposity in Canadian Aboriginal youth in comparison to their non-Aboriginal peers. A recent community-specific study used WC and other measures to show that Canadian Cree children (9-12 years) living in northern Quebec were prone to central adiposity (Downs et al 2008; Ng et al 2006); however, findings from this same study were not reported in relation to a non-Aboriginal sample and may not be generalizable to Aboriginal youth of other ages from different geographic areas within Canada. Thus, the purpose of the present study was to assess total and central adiposity in Canadian Aboriginal and Caucasian youth matched by age, sex and maturity. It was hypothesized that Aboriginal boys and girls would have greater total and central adiposity in comparison to sex and age matched Caucasian boys and girls.

Methods

Participants

Data from 212 self-ascribed Aboriginal youth and 204 Caucasian youth from Saskatchewan, Canada were included in this study (N=416). Approval was obtained from the University Research Ethics Board; school boards and the school principals and teachers. Assent to all procedures was received from each participant along with written consent from their respective parent/guardian(s) prior to the study.

A letter introducing the study, along with an invitation to contact our research personnel for information, was mailed to approximately 20 community schools that had a majority enrolment of Aboriginal youth. If interest was expressed after the initial mailings, the school was contacted and provided with more information. All Aboriginal youth between 8 and 17 years attending these schools were invited to participate to recruit 10 males and 10 females in each chronological age group. In total, 352 self-ascribed Aboriginal youth completed parental consent forms, but for the purposes of this study, comparative data was required and only 212 met these criteria. Data collection took place from 2005 to 2006 with Aboriginal youth from 12 rural/reserve and 4 urban (i.e., population ≤ 200, 000) schools across one geographic region. Data from 204 Caucasian youth (8 - 17 years) participating in the Pediatric Bone Mineral Accrual Study (PBMAS) (1991-1997) (Bailey 1997; Bailey et al. 1999) were used for comparison, representing a similar geographic area. Details regarding participant recruitment and data collection for the PBMAS have been reported elsewhere (Bailey 1997; Bailey et al. 1999). In brief, the parents of 228 students (113 boys, 115 girls) of 375 eligible students attending two elementary schools in a mid-sized Canadian city (population approximately 200,000) provided written consent for their youth to be involved in this study and 220 were scanned using dual x-ray absorptiometry (DXA). For inclusion in the present analysis, a similar number of Caucasian participants were matched by age, sex and maturity status (i.e., age from peak height velocity) of the Aboriginal youth to ensure representation in each maturity category. Data collection for the Caucasian sample was conducted in the same lab and followed the same standardized protocols.

Measurements

Ethnicity was self-ascribed based on responses to a question that provided three different ethnic categories (i.e., First Nations, Métis and Inuit). Additionally, one question asked participants to identify their tribal group (e.g., Cree, Mohawk, Ojibwa, etc.). Assistance from the parent or teacher accompanying the youth was provided if he/she could not respond to this question on their own.

Participants wore light clothing with their shoes removed for all anthropometric measurements. Weight was measured in duplicate to the nearest 0.1 kg using a Tanita Solar (HS – 301) electronic scale. Height and sitting height were measured in duplicate to the nearest millimeter using a Harpenden Stadiometer (Holtain Ltd). Sitting height was calculated by subtracting the height of a standardized box from the participants' height. Waist circumference (WC) was measured in duplicate (in triplicate if the difference between the first two measurements exceeded 4 mm) with a flexible steel tape directly on the skin, at the level of the narrowest point between the lower costal border and the iliac crest at the end of a gentle expiration. If there was no point of noticeable narrowing, WC was measured midway between the two landmarks (Norton et al. 1996). The mean of all WC measurements was recorded. BMI (body mass/height^2) was determined from the mean measured weight and height and calculated to the nearest 0.01 kg/m^2. The International Obesity Task Force (IOTF) sex and age-specific reference standards (Cole et al. 2000) were used to classify youth as non-overweight (< the 90th percentile), overweight (≥ the 90th percentile) or obese (≥ the 97th percentile). Using the Third National Health and Nutrition Examination Survey (NHANES III) reference, participants who had a WC that met or exceeded the 85th percentile of sex and age-matched youth were considered to have central adiposity. NHANES III WC measurements were performed at the uppermost lateral border of the right iliac crest, which is generally comparable to the site of measurement used in this study (Wang et al. 2003).

In recognition of the potential confounding effects of normal growth and maturation on the level and distribution of adiposity, all participants were defined by both chronological and biological age. Chronological age was determined to decimal age value by subtracting birthdate from the assessment date and truncated using 1 year intervals (e.g., whereby the 15-year age group included data between 14.5 and 15.49 years). Measured sitting height was used to predict age at peak height velocity (APHV), an indicator of biological maturity (Mirwald et al. 2002). Biological age was determined by subtracting the chronological age of the individual at the time of measurement from the APHV. A continuous measure for biological age was generated and then truncated using 1-year intervals, for example, the -1 year from APHV group included observations between -1.49 and -0.50 years from APHV. These data were grouped into one of three maturity categories: 1) *pre-peak height velocity* (less than or equal to -1.0 yrs from APHV); 2) *peak height velocity* (-0.9 through 0.9 yrs from APHV); and 3) *post-peak height velocity* (1.0+ yrs from APHV).

Total body scans were completed on all participants using dual x-ray absorptiometry (DXA) technology (Hologic QDR-2000, fan beam mode for the PBMAS and Hologic Discovery 4500 *Wi*; Waltham, Mass., for our Aboriginal study). To develop a regression equation and conversion factors for total body and trunk fatness from the Hologic 2000 to the Hologic 4500, nine males and 15 females were measured on both Hologic instruments. Each scan lasted around 7 minutes, while the participant remained still, lying supine on the scan bed. Participants wore loose fitting clothing with all metal objects (jewelry, belts, etc.), socks and footwear removed. Standardized procedures were followed and a single nuclear medicine technician performed and analyzed all scans for consistency. Regional soft tissue mass was assessed using the standardized (i.e., manufacturer) regions of interest. Relative measures for total body fatness and trunk fatness were calculated as 100 times the ratio of total body fat and trunk fat mass to total body mass, respectively. Trunk adiposity index (TAI), which reflects that tendency of adipose to accumulate in the central region, was determined by the difference between relative measures of trunk fat and total fat (Leslie et al. 2007).

Statistical Analyses

Of the 416 youth in the study, 11 Aboriginal youth (7 girls and 4 boys) did not have complete data; therefore the number of participants in each analysis varied. Given that normal growth and maturation differs in boys and girls and can have a profound impact on adiposity (Malina 1996), all analyses were run for girls and boys separately. Distributions of continuous variables were assessed for normality and descriptives were summarized (Means ± Standard Deviations (SD)) by ethnicity and maturity. Independent t-tests were used to examine differences between the two ethnic groups in each maturity category (pre-peak height velocity; peak height velocity; post-peak height velocity). Categorical variables were summarized using proportions (BMI and NHANES centiles) and compared with Chi-square statistics (Fisher's Exact Test where appropriate). BMI cut-offs proposed by the IOTF were used to classify non-overweight (non-OW), overweight (OW) and obese (OB); however, for this analyses, BMI was dichotomized into non-OW or OW, which included youth classified as OB (hereinafter referred to as OW/OB). NHANES III references were applied to establish central adiposity.

To test the primary hypothesis, analysis of covariance (ANCOVA) was run in girls and boys consecutively, where total body fatness (TBF) and trunk fatness (TF) were the dependent variables, and ethnicity the independent variable. Biological age, height and chronological age were entered as covariates. All analyses were performed using SPSS (Version 16.0, Chicago, IL) and a p-value of less than 0.05 was taken to indicate a statistically significant effect.

Results

Youth in this study (n = 416) included approximately equal numbers of girls (n = 221: 107 Caucasian, 114 Aboriginal) and boys (n = 195: 97 Caucasian, 98 Aboriginal) in each ethnic group. Among the participants who were of Aboriginal ethnicity, 85% (n = 179) self-identified as First Nations, while 15% (n = 33) were Métis. No youth self-ascribed as Inuit. The majority of First Nations respondents further identified themselves as Cree. However, small sample sizes in each tribal subgroup necessitated retaining all participants into one broad category (i.e., Aboriginal) for analyses. Descriptive characteristics for all girls and boys are included in Tables I and II, respectively. All youth in the study were ±5.0 years from age at peak height velocity (APHV), with a mean biological age of +0.3 yrs APHV. In the total sample of girls, mean biological age was 1.24 (± 1.7) yrs APHV for Aboriginals and 0.86 (± 1.57) yrs APHV for Caucasians ($p > 0.05$); mean chronological age was 13.3 (± 2.2) yrs for Aboriginal girls and 12.8 (± 1.7) yrs in Caucasian girls ($p > 0.05$). In the total sample of boys, mean biological age was -0.56 (± 2.3) yrs APHV for Aboriginals and -0.48 (± 1.7) yrs APHV for Caucasians ($p > 0.05$), while mean chronological age was 12.8 (± 2.7) yrs for Aboriginals and 13.0 (± 1.9) yrs for Caucasians ($p > 0.05$). Height and weight aligned by CDC age- and sex-specific reference standards are displayed in Figure 1.

Across all maturity categories, Aboriginal girls had, on average, higher body weights, higher BMIs and greater TBF and overweight/obesity compared to their Caucasian peers, with differences most apparent at post peak height velocity (see Table I and Figure 2). Similarly, across all maturity categories, ethnic differences in girls emerged in the distribution of adiposity; although these differences were more pronounced than differences in indicators of overall adiposity (i.e., weight, BMI, TBF and overweight/obesity) (Table I and Figures 2 & 3). For example, whereas the prevalence of OW/OB was higher among Aboriginal girls only in post peak height velocity ($p < 0.05$), the proportion of Aboriginal girls considered to have central adiposity (CA) (i.e., a WC that met or exceeded the 85th percentile) was greater than the proportion of Caucasian girls across all maturity categories ($p < 0.01$) (Table I). In addition, WC and trunk adiposity index (TAI), measures of central adiposity, were significantly greater in Aboriginal girls compared to Caucasian girls in all maturity categories ($p < 0.01$) (Figure 2).

When boys were examined, differences between Aboriginals and Caucasians emerged for nearly all variables, particularly in pre-peak height velocity (Table II). On average, Aboriginal boys were younger and shorter, with higher BMIs, WCs and TAIs in comparison to Caucasian boys in pre-peak height velocity ($p < 0.01$) (Figure 2). When proportions were compared, prevalence of OW/OB was higher among Aboriginal boys, but this difference was significant only in pre-peak height velocity ($p < 0.05$). Across all maturity categories, prevalence of CA was higher in Aboriginal boys in pre-peak height velocity ($p < 0.01$) and post-peak height velocity ($p < 0.01$) (Table II and Figure 2). TBF and TF also were higher in Aboriginal boys, but at pre-PHV and PHV only ($p < 0.01$) (Figure 3).

Results using ANCOVA with girls with complete data (n = 214: 107 Caucasian, 107 Aboriginal) showed ethnic differences in TBF existed (covariates: height, biological and chronological age) ($p<0.01$). Aboriginal girls had, on average, 5.4 % more TBF and 6.0% more TF than Caucasian girls (Adjusted R-sq = 0.2, $p < 0.01$). Complete data from boys (n = 191: 97 Caucasian, 98 Aboriginal) showed that Aboriginals had, on average, 7.6% more TBF and 8.3 % more TF than Caucasians when height, biological age, and chronological age were covariates (Adjusted R-sq = 0.2, $p<0.01$). Mean TBF and TF for girls and boys are shown in Figures 3 and 4.

Discussion

Although there is mounting evidence to suggest that obesity is highly prevalent in Aboriginal youth (Hanley et al. 2000; Katzmarzyk 2008; Katzmarzyk and Malina 1998; Potvin et al. 1999; Shields 2005), this study adds to the literature by maintaining a more comprehensive approach to assessing adiposity in a sample of Canadian Aboriginal youth in reference to their age, sex and maturity – matched Caucasian peers. In 1998, Katzmaryzk and Malina showed that overall and centrally located subcutaneous adiposity were disproportionately high in Aboriginals compared to individuals of European ancestry living nearby using estimates from a large sample of adults and a relatively small sample (n = 21) of youth (5 – 19 years). Our findings are in agreement with Katzmarzyk and Malina (1998) and other Canadian studies (Katzmarzyk 2008; Potvin et al. 1999; Shields 2005; Tremblay et al. 2005), which suggest that Aboriginals generally have greater prevalence rates of obesity in comparison to Caucasians. The current study, however, is unique in that it addressed some of the methodological shortcomings and reported both total and central adiposity in over 200 Aboriginal youth. The combination of measures used in this study likely improved its quality (Nassis et al. 2006), as the ethnic differences seen in the findings from this study may not have emerged had we relied solely on a single measure such as BMI.

The use of DXA, an accurate and precise measure of adiposity (Ellis et al. 2004), is also a strength of this study. Our findings using DXA suggest that Aboriginal youth have greater relative TBF and TF in comparison to their Caucasian counterparts and reinforce our findings using WC measures. Like the present study, the First Nations bone health study (Leslie et al. 2007) used DXA to show Aboriginal women had greater trunk fat accumulation than Caucasian women, which persisted after adjustment for BMI, body mass and socio-demographics. To our knowledge, no other studies except the present have assessed adiposity in Canadian Aboriginal youth and their Caucasian peers using DXA in conjunction with other measures.

Perhaps the most unique feature of the present study is that we were able to adjust for biological maturity. Research has shown that there is large variability in biological growth between youth of the same chronological age (Iuliano-Burns et al. 2001; Marshall et al. 1970) and that adiposity changes in boys and girls will differ and can be associated with stage of biological maturity (Malina 1996). Thus, it was expected that increases in adiposity would be seen in girls with advancing age and maturity, but that the opposite would be true in boys as they put on lean tissue mass with growth and maturity. Although it was not our intent to investigate sex differences, our results support this conjecture, as girls had greater TBF and TF in comparison to boys. More importantly, when data were aligned by maturity for boys and girls, Aboriginal youth generally had a higher prevalence of OW/OB and a substantially greater degree of CA in comparison to their Caucasian peers. This suggests that there may be a tendency for Aboriginal youth to accumulate excess adipose in and around the central region in addition to the normal adiposity changes that occur during adolescence. These findings may be clinically significant, given the metabolic differences in fat depots, and, if typical of other Aboriginal youth, imply that a large proportion may be predisposed to metabolic disorders at a very young age.

While controlling for the confounding aspects of biological maturation helps to establish the level and distribution of adiposity in growing Aboriginal youth, the reason for the ethnic differences remains unclear. Neel (1962) first proposed that a ‘thrifty genotype’ offered a survival advantage to populations subject to periods of famine by favoring caloric conservation when food was abundant by developing a ‘thrifty’ metabolism. The ‘thrifty genotype hypothesis’ has built on this idea, suggesting that a thrifty metabolism has now become a liability in Aboriginal peoples because it contributes to obesity and T2D when combined with the nutritional excess and physical inactivity associated with modern times. Dyck and colleagues (2002) have further speculated that the thrifty genotype would be particularly advantageous for a population’s survival if it increased the likelihood of successful pregnancies, proposing the ‘hefty fetal phenotype hypothesis’ (HPH), which suggests that the thrifty genotype evolved to create well nourished infants and has become a modern liability leading to increased rates of gestational diabetes mellitus (GDM). Thus, an ancient survival mechanism (i.e., one which favors caloric conservation in women of childbearing age, as well as in their unborn), could optimize fetal nutrition and promote healthy birth weights, but with the continuous food supply and physical inactivity today, could predispose Aboriginal women to GDM and a tendency towards a high birth weight (HBW) (Dyck et al. 2001; 2005; Silverman et al. 1998). This hypothesis is relevant to the present study since research has shown that Aboriginal ethnicity is an independent predictor of gestational diabetes mellitus (GDM) and that the offspring of Aboriginal women with GDM are more likely to develop childhood obesity, insulin resistance and early onset of T2D (Dyck et al. 2001; 2005; Silverman et al. 1998). It is hoped that the results of this study, as well as the questions it will raise, will provoke further research into understanding the complexity of factors related to adiposity in the Aboriginal population.

As with any investigation, this study has its limitations. Although our results were adjusted for biological maturity, a longitudinal study would be required to determine how adiposity in the two ethnic groups would evolve over time and the implications of our findings in terms of health risks can only be speculated. Given secular trends of childhood obesity in Canada (Tremblay et al. 2000) and evidence to suggest that fat distribution has also changed over the past few decades (i.e., youth have higher WC values for a given BMI) (McCarthy et al. 2003), it is possible that the time elapsed between data collection for the Aboriginal study (2005-06) and the PBMAS (1991-1997) may have contributed to the ethnic differences in adiposity observed in this study. Other study limitations include a lack of information on the number of youth who received information about the study but declined (therefore participation rate cannot be determined) and sample size limitations, which necessitated collapsing all Aboriginal youth (urban/rural/reserve) into the same group for analyses. Given this, questions regarding the effects of this admixture cannot be answered.

In conclusion, Canadian Aboriginal youth in this study differed from their Caucasian peers in both total and central measures of adiposity. These differences persisted after adjustment for confounding variables and may contribute to observed differences in T2D, MetS and related cardiovascular conditions prevalent in Canadian Aboriginal adults. Future research should assess both adiposity and its distribution and be directed at understanding the impact of an array of factors (i.e., genetics, sex, maturity, nutrition, physical activity, culture, socioeconomic status and the built environment) on adiposity so that specific interventions targeted at this understudied, yet vulnerable population, can be developed (Willows 2005).

Acknowledgements

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Table I. Descriptive Characteristics of Girls (n = 221) by Maturity Category and Ethnic Group. Data are presented as means (± SD).

	Maturity Category **Pre-peak height velocity (n =43)**		**Peak height velocity (n =80)**		**Post-peak height velocity (n =98)**	
	AB (n =19)	**CN (n = 24)**	**AB (n = 39)**	**CN (n = 41)**	**AB (n = 42)**	**CN (n = 56)**
Age (chronological yrs)	9.9 (1.1)	10.6 (1.3)	12.6 (0.9)	12.6 (1.0)	14.9 (1.5)	14.4 (1.1) *
Biological age (yrs from APHV)	-1.5 (0.7)	-1.5 (0.7)	0.6 (0.5)	0.7 (0.5)	2.6 (0.8)	2.4 (0.6)
Height (cm)	143.7 (5.7)	146.5 (8.2)	157.2 (4.8)	159.0 (6.6)	165.0 (4.2)	162.5 (5.4)*
Weight (kg)	41.7 (8.8)	38.8 (10.2)	51.5 (10.7)	50.0 (10.2)	67.9 (14.0)	57.0 (11.1) **
BMI (kg·m^{-2})	20.2 (4.1)	17.8 (3.2) *	20.7 (3.8)	19.7 (3.4)	24.9 (4.4)	21.6 (3.8) **
BMI z-score	-0.2 (0.9)	-0.7 (0.7)*	-0.0 (0.9)	-0.3 (0.7)	0.9 (1.0)	0.2 (0.9) **
Overweight/obesity (%)$^{¢}$	47.4	20.8	25.6	19.5	50.0	26.2 *
Waist circumference (cm)	71.6 (10.4)	61.1 (7.7) **	74.1 (9.7)	66.0 (7.9) **	83.5 (13.1)	69.3 (8.2) **
Waist circumference z-score	-0.05 (0.8)	-0.90 (0.6) **	0.15 (0.8)	-0.51 (0.6) **	0.92 (1.1)	-0.2 (0.7) **
Central adiposity (%)$^{¥}$	36.8	4.2**	25.6	4.9 ^{FE**}	33.9	7.1^{FE**}
Trunk adiposity index	-0.6 (2.9)	-2.8 (3.2) *	-1.7 (2.2)	-3.2 (3.2) *	0.3 (3.0)	-2.1 (2.9) **

SD = standard deviation; AB = Aboriginal; CN = Caucasian; APHV = age at peak height velocity; BMI = body mass index. Ethnic differences were analyzed by independent t-tests (continuous variables) or χ^2 tests (categorical variables), where * = significant at the 0.05 level and ** = significant at the 0.01 level. FE = Fishers Exact Test.
¢ IOTF body mass index cut-off values. ¥ Waist circumference cut-off values that met or exceeded the 85th percentile for NHANES III data.

Table II. Descriptive Characteristics of Boys (n = 195) by Maturity Category and Ethnic Group.
Data are presented as means (± SD) unless otherwise stated.

	Maturity Category					
	Pre-peak height velocity (n =110)		**Peak height velocity (n =48)**		**Post-peak height velocity (n =37)**	
	AB (n =56)	**CN (n = 54)**	**AB (n = 19)**	**CN (n = 29)**	**AB (n = 23)**	**CN (n = 14)**
Age (chronological yrs)	10.9 (1.4)	11.7 (1.3) **	14.4 (1.0)	13.9 (0.7) *	16.4 (1.3)	16.1 (0.9)
Biological age (yrs from APHV)	-2.3 (1.0)	-1.8 (1.0) **	0.5 (0.5)	0.7 (0.5)	2.7 (0.9)	2.4 (0.5)
Height (cm)	146.8 (9.4)	151.3 (8.1) **	171.2 (7.5)	168.1 (9.2)	180.2 (6.3)	178.9 (6.5)
Weight (kg)	44.9 (12.5)	42.0 (10.3)	60.3 (11.8)	54.3 (10.0)	79.8 (21.1)	72.5 (12.9)
BMI ($kg \cdot m^{-2}$)	20.6 (4.3)	18.2 (3.4) **	20.6 (3.9)	19.1 (2.4)	24.4 (5.5)	22.6 (3.6)
BMI z-score	-0.07 (1.0)	-0.6 (0.8) **	-0.06 (0.9)	-0.4 (0.5)	0.8 (1.2)	0.4 (0.8)
Overweight/obesity (%)¢	41.4	20.4 *	26.3	6.9	47.8	28.6
Waist circumference (cm)	72.8 (12.2)	64.6 (8.3) **	76.2 (8.8)	68.2 (5.6) **	86.0 (15.3)	77.2 (7.8)
Waist circumference z-score	0.05 (1.0)	-0.6 (0.7) **	0.32 (0.7)	-0.32 (0.5) **	1.1 (1.2)	0.4 (0.6)
Central adiposity (%)¥	36.8	4.2 **	15.8	0.0	30.4	0.0 ^{FE**}
Trunk adiposity index	-1.8 (2.2)	-4.2 (2.2) **	-1.0 (2.0)	-2.9 (1.3) **	-0.03 (1.7)	-1.8 (1.5) **

SD = standard deviation; AB = Aboriginal; CN = Caucasian; APHV = age at peak height velocity; BMI = body mass index. Ethnic differences were analyzed by independent t-tests (continuous variables) or χ^2 tests (categorical variables), where * = significant at the 0.05 level and ** = significant at the 0.01 level. FE = Fishers Exact Test.
¢ IOTF body mass index cut-off values. ¥ Waist circumference cut-off values that met or exceeded the 85th percentile for NHANES III data.

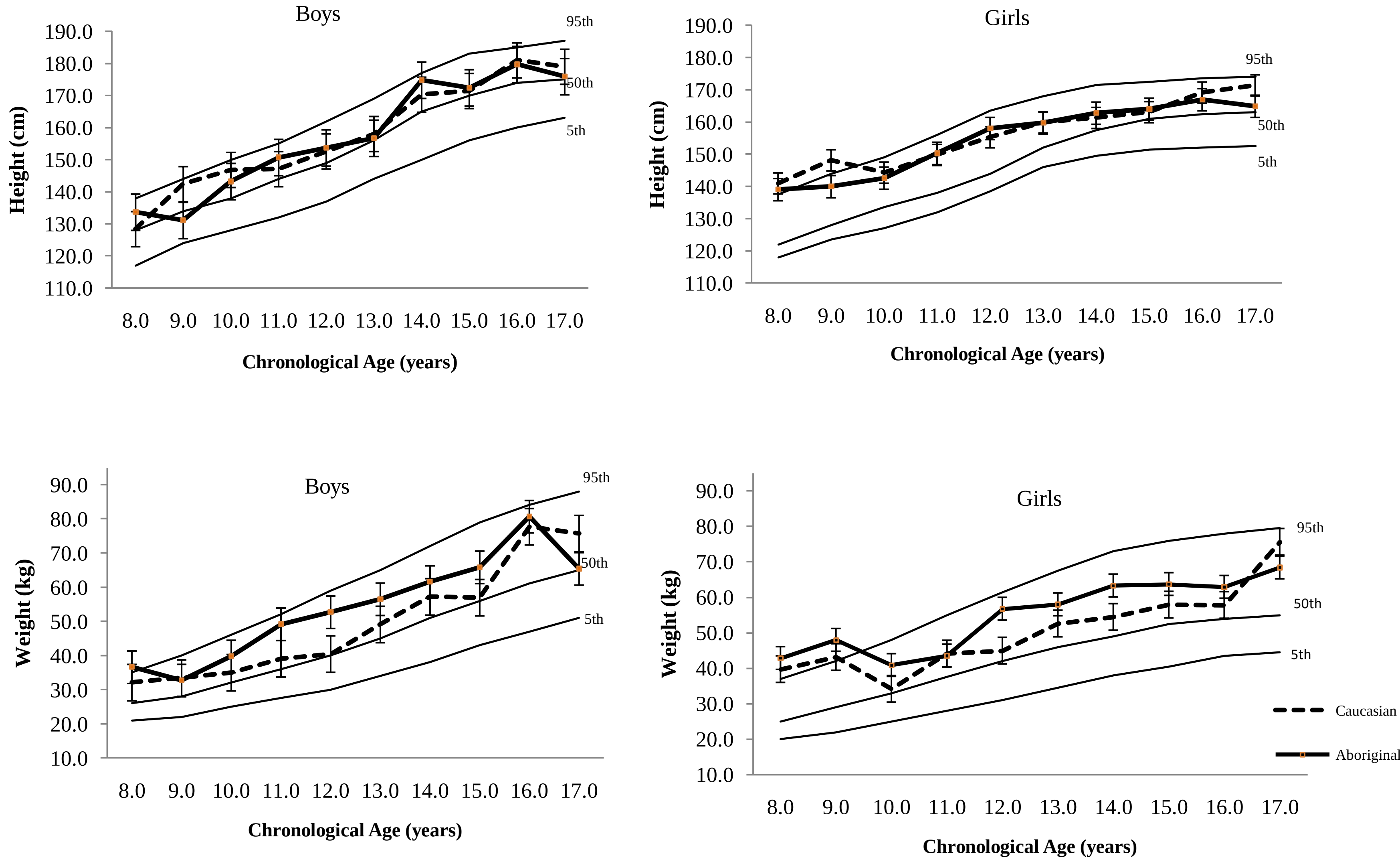

Figure 1. Height and weight by sex plotted against CDC reference standards (5th, 50th, and 95th).

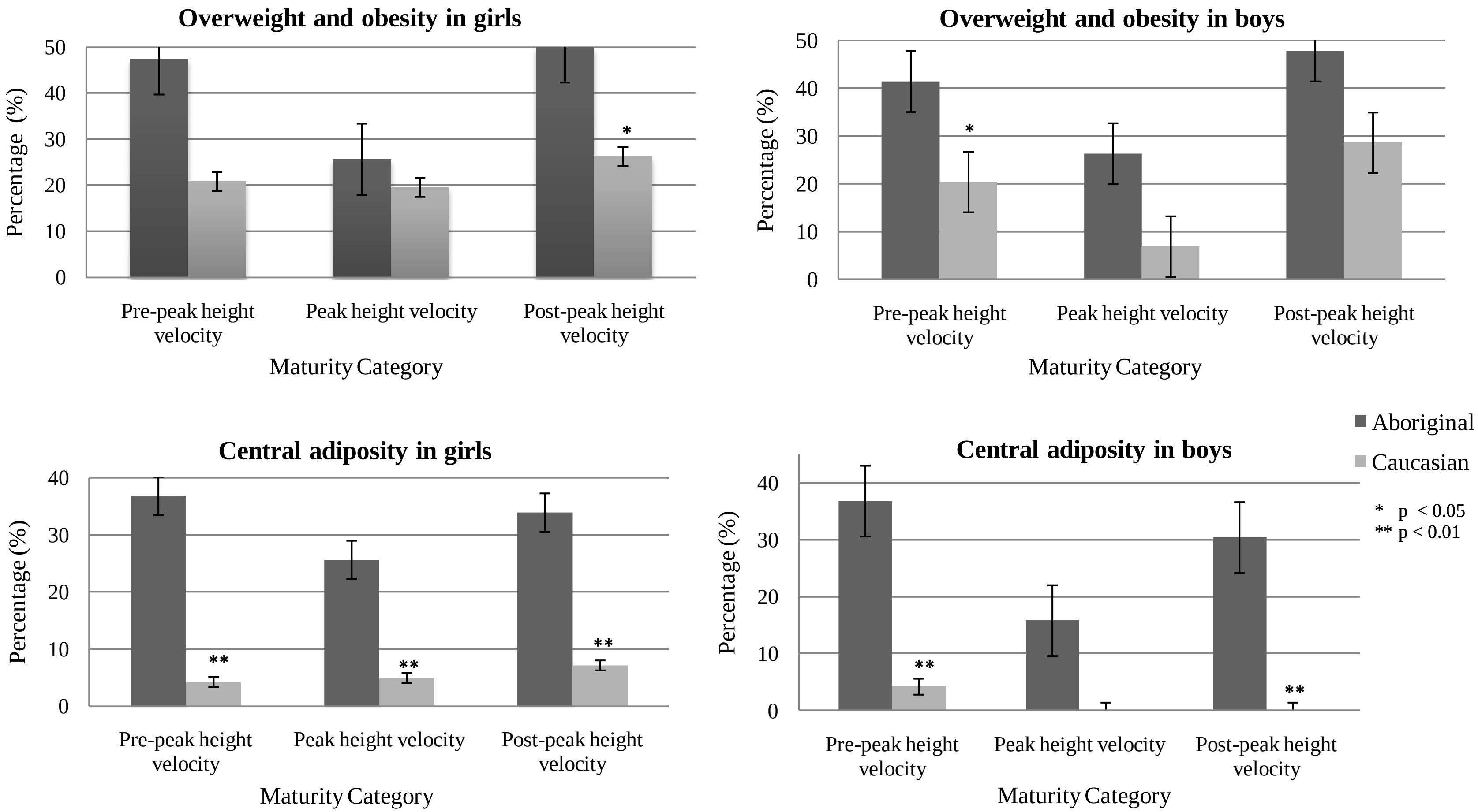

Figure 2. Prevalence of overweight/obesity and central adiposity in girls and boys represented by maturity.

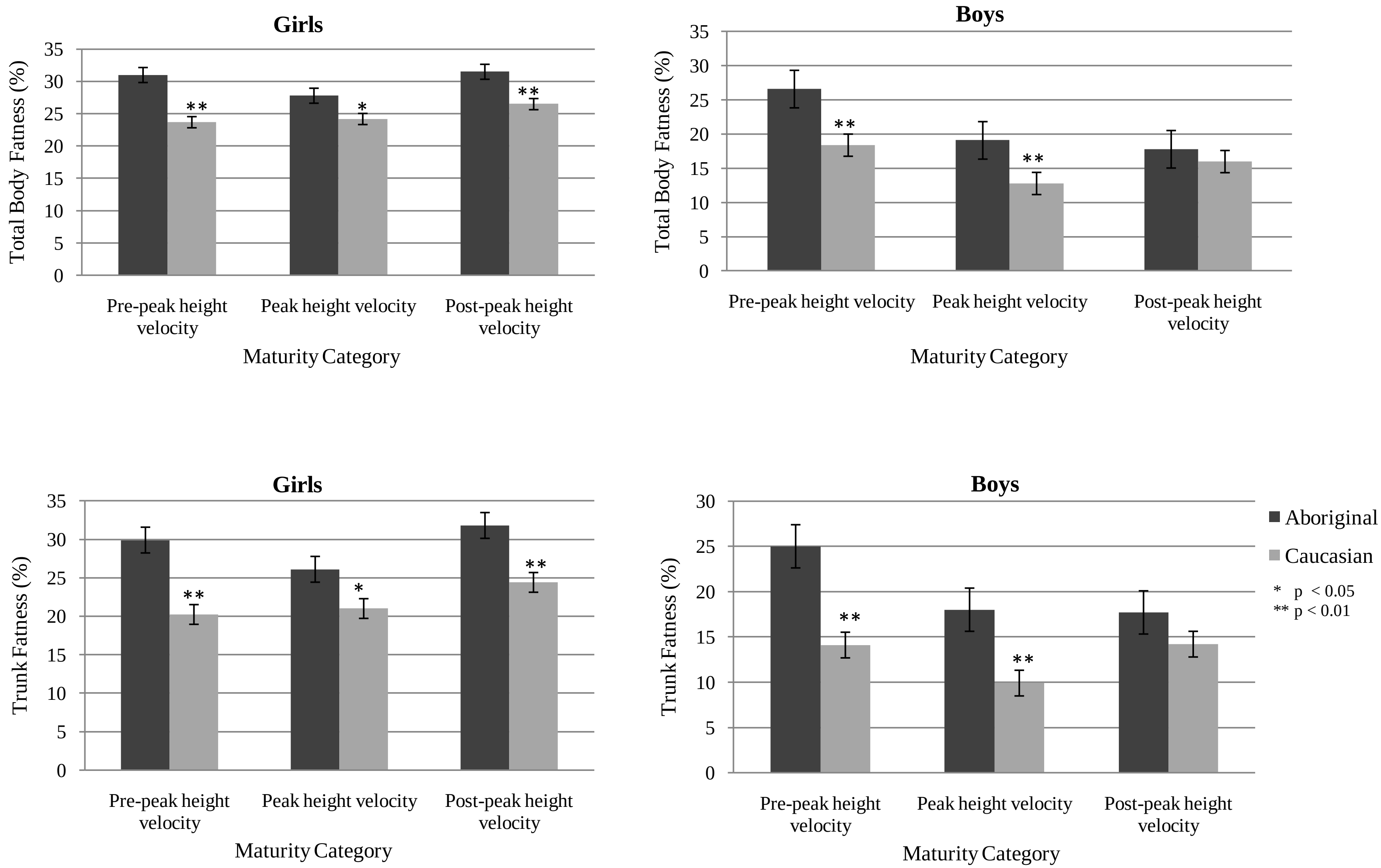

Figure 3. Ethnic differences in total body fatness and trunk fatness represented by maturity.

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Paper II: Physical activity of Canadian Aboriginal youth: the role of ethnicity and sex

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ABSTRACT

Purpose: To assess the role of ethnicity and sex on physical activity (PA) and identify the proportion of Aboriginal youth meeting international PA and T.V. viewing recommendations. **Methods:** The Physical Activity Questionnaire for Children or Adolescents (PAQ-C/A; 1 low 5 high) was administered to 205 Aboriginal and 204 Caucasian youth (8 – 17 years). One hundred thirteen of the 205 Aboriginal youth also completed the Modifiable Activity Questionnaire for Adolescents (MAQ-A) to estimate activity energy expenditure (AEE) (i.e., kilocalories per kilogram of body weight per day; KKD) and a self-report checklist to assess T.V. viewing. Anthropometrics were measured and body mass index, age at peak height velocity (APHV) and somatic maturity were determined. Descriptives (Means ± Standard Error) with independent t-tests and analysis of covariance (ANCOVA) (covariates: chronological age, biological age, height and body mass) were used for analyses. **Results:** Aboriginal boys reported lower adjusted PA (PAQ-C/A = 2.8 ± 0.7) than Caucasian boys (3.1 ± 0.7) ($P<0.05$), while PA scores of Aboriginal and Caucasian girls were comparable (PAQ-C/A = 2.7 ± 0.6 vs. 2.9 ± 0.6) ($P>0.05$). When AEE data were analyzed by sex, Aboriginal boys reported higher adjusted AEEs (7.6 KKD ± 0.5) in comparison to girls (4.8 KKD ± 0.5) ($P<0.01$) and the proportion of Aboriginal boys (47%) meeting PA recommendations (i.e., ≥8KKD) was greater than Aboriginal girls (30%) ($P<0.05$). Additionally, a greater percentage of Aboriginal boys vs. girls (36% vs. 15%) were meeting recommendations for T.V. viewing (<2hrs/day) ($P<0.05$). **Conclusions**: Data from this study suggest the PA levels of both Aboriginal and Caucasian youth are less than optimal and that Aboriginal boys have higher PA levels, with a greater proportion meeting the recommendations for PA and T.V. viewing in comparison to girls. Future research should examine the determinants of PA by ethnicity and sex to establish clear guidelines for the development of interventions targeted for Aboriginal youth. **Key words:** BIOLOGICAL MATURITY, ABORIGINAL YOUTH, MAQ-A, T.V., ACTIVITY ENERGY EXPENDITURE, ACTIVITY LEVEL.

INTRODUCTION

Research has shown that Aboriginal (First Nations, Métis and Inuit) youth are more likely to develop obesity and related metabolic disorders such as Type 2 diabetes (T2D) than their non-Aboriginal peers (Bobet 1997; Health Canada 2001; Katzmarzyk 2008; Young et al., 2000) and that Aboriginal youth typically experience an earlier onset of these conditions (Dean, 1998; Health Canada 2003). The antecedents of many "adult" diseases perpetuated by Aboriginal children, such as metabolic syndrome (MetS), may be prevented through regular physical activity (Klein-Platat et al. 2005; Kriska et al. 2003; Liu et al. 2006; McGavock et al. 2007; Warburton et al. 2006). Physical activity (PA) enhances many aspects of physical and mental health, including regulation of body weight, blood glucose, triglyceride levels, blood pressure, anxiety and depression and improved cognitive function, self esteem and bone health (Stensel et al. 2008; Torrance et al. 2007; Warburton et al. 2006). Evidence also suggests physical activity is inversely related to waist circumference (Klein-Platat et al. 2005), which, in combination with improved glucose tolerance and insulin sensitivity, can significantly reduce the risk for obesity, MetS and T2D (McGavock et al. 2007). Findings from the First Nations Regional Longitudinal Health Survey (RLHS) indicate that Aboriginal youth who participate in daily physical activity are more likely eat a balanced diet and report excellent health than youth who are not active on a regular basis and that physically inactive Aboriginal youths (12-17yrs) are nearly twice as likely to be obese than their physically active counterparts (Seto et al. 2006). Coupled with the beneficial physical effects on health, physical activity can also serve to reinforce social networks within the Aboriginal community (Coble and Rhodes 2006), which can positively influence emotional health. Thus, physical activity has large potential for improving the health of Aboriginal youths (Bunt et al. 2003; Kriska et al. 2003; Liu et al. 2006; Mitchell 2008).

Although physical activity is essential for chronic disease prevention (Janz et al. 2002; Kriska et al. 2003; Warburton et al. 2006), data suggest physical activity levels in Canadian youth are well below that required for maintenance of health and protection from future disease (Active Healthy Kids Canada 2009). Recent objective data showed 87% of Canadian children and youth were not meeting the guideline of 90 minutes of physical activity per day (Active Healthy Kids Canada 2009). Current national data also indicate a mere 10% of Canadian youth are meeting the recommendations for screen time (less than two hours per day) and many youth get close to six hours per day in their leisure time (Active Healthy Kids Canada 2009). Results from the 2007-2009 Canadian Health Measures Survey also indicate that physical fitness levels of Canadian children have significantly declined (Tremblay et al. 2009). While national data are lacking for Aboriginal youth, a community specific study that assessed physical activity and physical fitness levels among Canadian Aboriginal youths using pedometers showed that less than half (i.e., 49%) of Cree children (aged 9-12 years) were sufficiently active for health benefits (Downs et al. 2008; Seto et al. 2006). Earlier work with Cree youth (grades 4-5 and 8-9) from Quebec has also reported sub-optimal physical activity levels with a mean of 2.7 sessions physical activity weekly and 13 hours per week watching T.V. and/or playing video games (Bernard et al. 1995).

While evidence suggests physical activity may be lower in minority groups (Bryan et al. 2006), more data are needed to confirm this supposition. A recent national study by Katzmarzyk (2008) found no ethnic differences in the prevalence of physical inactivity and similar relationships between physical activity and obesity in Aboriginal and non-Aboriginal Canadians. Given that hypokinetic diseases such as obesity and T2D are highly prevalent in the Aboriginal population and their health is generally considered poorer in comparison to non-Aboriginal Canadians (Dean 1998; Harris et al. 1996; Health Canada 2001; Young et al. 2000), there is a call to action to improve the physical activity behaviors in this ethnic population. Since only a handful of studies (Hanley et al. 2000; Horn et al. 2001; Katzmarzyk 2008) have examined physical activity and/or T.V. viewing in Canadian Aboriginal youth, it would be beneficial to establish a scientific knowledge base of these behaviors (Willows 2005; Young and Katzmarzyk 2007). Although efforts have recently been made to improve our understanding of physical activity in Aboriginal Canadians (Bryan et al. 2006; Katzmarzyk 2008; Ng et al. 2006;Young and Katzmarzyk 2007), this paucity of data is incongruent with the relatively large volume of information on the health of the Canadian Aboriginal populations (Young and Katzmarzyk 2007). Furthermore, few studies have examined physical activity in relationship to sex and biological maturity, which have demonstrated growth and maturation associated variation in the physical activity behaviors of boys and girls (Sherar et al. 2007; Thompson et al. 2003). Understanding the relationship between ethnicity, sex and physical activity behavior, for example, would be beneficial for identifying physical activity patterns and developing culturally appropriate intervention programs (Bryan et al 2006; Coble and Rhodes 2006).

The purpose of this study was to assess the role of ethnicity and sex on physical activity (PA) levels and identify the proportion of Aboriginal youth meeting international PA and T.V. viewing recommendations. Given that sex and age differences in children’s physical activity may be diminished with research that accounts for biological maturation (Sherar et al. 2007; Thompson et al. 2003), biological age was controlled for to minimize PA differences associated with maturation. It was hypothesized that the physical activity levels of Aboriginal youth would be lower than their Caucasian peers; that the majority of Aboriginal youth would not meet international PA and T.V. viewing recommendations; and that Aboriginal boys would have higher adjusted activity energy expenditures (AEE) than Aboriginal girls.

METHODS

Participants

Data from 352 self- identified Aboriginal youth (i.e., majority First Nations) and 204 Caucasian youth from Saskatchewan, Canada, were included in this study (N=556). Approval was obtained from the University Research Ethics Board; school boards and the school principals and teachers. In addition, the First Nation Reserve communities involved in this research provided verbal consent for their youth to take part in this project. Assent to all procedures was received from each participant along with written consent from their respective parent/guardian(s).

Procedures for recruitment and data collection for Aboriginal youth in this study have been previously described (Anderson et al. 2010). In total, written consent was obtained from 352 self-identified Aboriginal youth. For the purposes of this study, complete comparative data was required; 238 Aboriginal youth met these criteria. Data collection took place between 2005 and 2006 with Aboriginal youth from 12 reserves and 4 small to mid-sized (i.e., population $\leq$ 250, 000) urban schools within central Saskatchewan. Comparative data from 204 Caucasian youth (8 - 17 years) was taken from participants of the University of Saskatchewan's Pediatric Bone Mineral Accrual Study (PBMAS) (1991-2007) (Bailey et al. 1999) representing a similar geographic region. Details regarding participant recruitment and data collection for the PBMAS have been reported elsewhere (Bailey et al. 1999). In brief, between 1991 and 1993 the parents of 228 students (113 boys, 115 girls) of 375 eligible students attending two elementary schools in Saskatoon, Canada (population approximately 250,000) provided written consent for their youth to be involved. Aboriginal and Caucasian participants were matched by age, sex and maturity status (age from peak height velocity). Data collection for the Caucasian sample was conducted in the same lab and followed the same standardized protocols, although up to 10 years previously.

Measures

Demographics. Ethnicity was self-identified based on responses to a question that provided three different ethnic categories (i.e., First Nations, Métis and Inuit). Additionally, one question asked participants to identify their tribal group (e.g., Cree, Mohawk, Ojibwa, etc.). Assistance from the parent or teacher accompanying the youth was provided if he/she did not understand the survey questions.

Geographic location was derived from the participants' current residence and classified as either urban or rural based on the school they were attending using the 2002 Canadian Census dictionary. For the purposes of this study, all youth from rural and reserve schools were considered together in one category, hereinafter referred to as "reserve" in this paper.

Age and Biological Maturity. In recognition of the potential confounding effects of normal growth and maturation on physical activity, all participants were defined by chronological and biological age. Chronological age was determined to decimal age value by subtracting birthdate from the assessment date and truncated using 1 year intervals (e.g., whereby the 15-year age group included data between 14.5 and 15.49 years). In addition to height, age and body mass, sitting height was used to predict the age when peak height velocity (APHV) was likely to occur (Mirwald et al. 2002). Years from APHV, an indicator of biological maturity, was determined by subtracting the chronological age of the individual at the time of measurement from the APHV (Mirwald et al. 2002). A continuous measure for biological age was generated and then truncated using 1-year intervals, for example, the -1 year from APHV group included observations between -1.49 and -0.50 years from APHV. These data were grouped into one of three maturity categories for statistical analyses: 1) *pre-peak height velocity* (less than or equal to -1.0 yrs from APHV); 2) *peak height velocity* (-0.9 through 0.9 yrs from APHV); and 3) *post-peak height velocity* (1.0+ yrs from APHV).

Physical Activity and T.V. Two self report measures were used to assess physical activity behaviors: 1) the Physical Activity Questionnaire for Children (PAQ-C) and/or the Physical Activity Questionnaire for Adolescents (PAQ-A) (Crocker et al. 1997), hereinafter referred to as the PAQ-C/A. The PAQ-C/A was used to compare physical activity levels in Aboriginal and Caucasian youth. The Modifiable Activity Questionnaire for Adolescents (MAQ-A) (Kriska et al. 1990) was used to estimate activity energy expenditure (AEE) in Aboriginal youth. Additionally, a self report checklist to assess television viewing provided an indication of sedentary behavior in Aboriginal youth.

The PAQ-C, which consists of an activity checklist and several questions regarding physical activity during the weekday and on the weekend, was designed to assess moderate to vigorous physical activity and provide a general measure of habitual physical activity for children grades three and older (Crocker et al. 1997). For high school students, the PAQ-A omits one question that asks about physical activity at recess. All items on the PAQ-C/A are scored, summed and averaged, with higher scores indicating higher levels of physical activity. The use of a 5-point rating results in a normal distribution of physical activity scores. The PAQ-C/A has demonstrated good internal consistency, reliability and validity, with moderate relationships to teacher evaluations of activity, Caltrac motion sensors, 7-day activity recalls and leisure-time activity scales (Crocker et al. 1997).

The MAQ-A, developed to assess physical activity behavior in ethnic populations (Kriska et al. 1990), is a reliable and valid self-reported measure suitable for use in youth (Aaron et al. 1995). Designed for easy modification to maximize its feasibility and appropriateness in a variety of minority populations (Kriska 2000; Kriska et al. 1990), the MAQ-A has been used in previous studies with Aboriginal populations (Hanley et al. 2000; Kriska et al. 2003). Given that Coble and Rhodes (2006) suggest that physical activity preferences in young Aboriginals have moved away from traditional activities to more sport and lifestyle activities such as baseball, the MAQ-A was modified to include a menu of both traditional, culturally appropriate and sport/lifestyle activities. Participants identified all organized and non-organized leisure activities performed over the past 4 weeks and classified them as light, moderate, or vigorous intensity. For each activity listed, the product of the metabolic cost (METs), average duration in minutes, and frequency for the week was calculated and then divided by the number of days in the week. The value of each activity was summed to yield total KKD (kilocalories per kilogram of body weight per day), with greater KKDs indicative of higher physical activity. For our analyses, data were dichotomized into two groups using an international cut-point of 8KKD, which is associated with optimal childhood health and development (Craig et al. 1999). Appended to the MAQ-A questionnaire was a self-report checklist to assess time spent on weekdays and weekends watching television. For our analyses, data regarding T.V. were dichotomized using a cut-point of 2hr/day, as per commonly cited recommendations (American Academy of Pediatrics 2007).

Data Analyses

Given that normal growth and maturation differs in boys and girls and can influence physical activity (Thompson et al. 2003), all analyses were run for girls and boys separately.

Distributions of continuous variables were assessed for normality and descriptives were summarized (Means ± Standard Deviations (SD) or Standard Error (SE)) by ethnicity and sex. Independent t-tests detected differences in the physical characteristics of the two ethnic groups, represented by chronological and biological age band, in boys and girls separately.

To determine whether physical activity levels (PAQ-C/A activity scores) differed between the two ethnic groups, independent t-tests and analysis of covariance (ANCOVA) were run for boys and girls consecutively (chronological age, biological age, height and body mass were entered as covariates). To test the second hypothesis, ANCOVA were used to examine differences in physical activity levels of Aboriginal boys and girls (dependent variables: PAQ-C/A activity score and KKD; covariates: chronological age, biological age, height and body mass). Categorical variables were summarized using proportions and compared with Chi-square (and Fisher's Exact, where appropriate) tests. Pearson r correlations were run to assess the relationship between the two physical activity questionnaires. All analyses were performed using SPSS (Version 16.0, Chicago, IL) and a p-value of less than 0.05 was taken to indicate statistical significance.

RESULTS

Among the participants who indicated they were Aboriginal, 85% self-identified as First Nations; 15% were Métis. The majority (i.e., 74%) of First Nations respondents further identified as Cree. The physical characteristics of the Aboriginal and Caucasian youth (n = 205 and 204, respectively) in this study represented by ethnicity and sex at each chronological age and biological age band are presented in Table 1. Ages at peak height velocity of the Aboriginal and Caucasian girls were similar (12.0 yrs in both ethnic groups; $P > 0.05$); likewise, there were no differences in the APHV for boys (13.4 yrs in Aboriginal boys vs. 13.5 yrs in Caucasian boys; $P > 0.05$). Changes in height and body mass were seen with advancing age in both ethnic and sex groups, with steady increases in height across 8-17 years for boys, and more dramatic increases in height between 10-13 years of age in girls. Changes in body mass in girls similarly showed greater increases between 10-12 years, while in boys, steady increases were seen until around age 13, after which a dramatic increase in body mass occurred. Similar patterns in height and body mass in girls and boys were seen with advancing biological age (see Table 1).

Unadjusted physical activity levels (as indicated by PAQ-C/A activity scores), aligned by chronological and biological age, are presented by ethnicity and sex in Figure 1. In

Aboriginal and Caucasian boys, physical activity levels increased with advancing chronological age (to about age 12) and then remained relatively stable. Ethnic differences in the physical activity levels of Aboriginal and Caucasian boys emerged at 11 and 12 years of age, with Caucasian boys reporting higher activity scores than Aboriginal boys ($P<0.05$). When data were aligned by biological age, findings showed significant differences in PA scores ($P<0.05$) at 3 and 4 years prior to APHV (see Figure 1). In girls, physical activity scores declined with advancing chronological and biological age in both ethnic groups. Overall, Caucasian girls had higher activity scores at 12 and 16 years of age ($P<0.05$) than their Aboriginal counterparts; however, these differences were diminished when data were aligned by biological age (i.e., a significant difference was seen only 4yrs post-APHV).

When PAQ-C/A scores were adjusted for chronological age, biological age, height and body mass, findings indicated Aboriginal boys (n = 188) (2.8 ± 0.1) reported lower scores in comparison to Caucasian boys (3.1 ± 0.1) ($P<0.01$). Although Aboriginal girls (n = 218) also reported lower activity scores (2.7 ± 0.1) than their Caucasian counterparts (2.9 ± 0.1), these differences were not significant ($P>0.05$). In general, these findings suggest that Aboriginal youth (particularly girls) had comparable PA levels to their Caucasian peers.

Descriptive results and physical activity behaviors of the Aboriginal youth by sex and biological maturity category are shown in Table 2. As indicated earlier, the majority of Aboriginal youth indicated they were First Nations, and of these, 74% self-identified themselves as Cree. However, small sample sizes in each ethnic and tribal subgroup necessitated retaining all participants into one broad category (i.e., Aboriginal) for analyses.

A correlation was found between the PAQ-C/A and MAQ-A ($r = 0.3$; $P<0.01$), although differences in physical activity levels between Aboriginal boys and girls were more apparent with the MAQ-A. For example, when PA levels were examined in adjusted models, AEEs of boys were similarly higher (7.6 KKD $\pm$ 0.5) than girls (4.8 KKD $\pm$ 0.5) (covariates chronological age, biological age, height and body mass) ($P<0.01$), while adjusted PAQ-C/A scores in Aboriginal boys and girls (2.9 ± 0.1 vs. 2.7 ± 0.1, respectively) did not differ ($P>0.05$). Likewise, activity scores attained from the PAQ-C/A showed Aboriginal boys had higher activity scores than Aboriginal girls at post-PHV ($P<0.01$) (Table 2). When unadjusted physical activity levels of Aboriginal boys and girls were compared by maturity category, notable sex differences also emerged, with Aboriginal boys reporting significantly higher KKD than Aboriginal girls ($P < 0.05$ and $P < 0.01$, at pre-PHV and post-PHV, respectively).

Nearly 40% of the Aboriginal youth in this study were not meeting the recommendations for physical activity (i.e. < 8 KKD). When data were aligned by maturity category, χ^2 showed that a greater proportion (35%, 37% and 46%) of Aboriginal boys were meeting the recommendations for physical activity (i.e., ≥ 8KKD) in comparison to Aboriginal girls (10%, 24% and 30%) (in Pre-PHV, PHV and Post-PHV, respectively) (see Figure 2), differences which were significant at pre-PHV and post-PHV ($P<0.05$ and $P<0.01$, respectively). While proportions meeting the recommendations for T.V. viewing were generally comparable across the two sex groups, at PHV nearly twice the amount of Aboriginal boys (36%) were meeting the recommendations (i.e., <2 hrs/day) compared to Aboriginal girls (15%) (Figure 3) ($P<0.05$).

DISCUSSION

The aim of this study was to assess the role of ethnicity and sex on PA levels and identify the proportion of Aboriginal boys and girls meeting international PA and T.V. viewing recommendations. While it is difficult to compare the present findings to other studies due to limited research and varying methodologies, our findings showed that, like Caucasian youth, physical activity levels in Aboriginal youth were less than optimal and decreased with increasing age and maturity. Although there were no differences in the PA levels of Aboriginal and Caucasian girls, differences were found between Aboriginal and Caucasian boys. These results are similar to a recent Canadian study that indicated that physical inactivity levels of Aboriginal youth (12 – 17 yrs) were not substantially different from their Caucasian peers (Katzmarzyk 2008).

In 2007, it was reported that most Canadian youth were not moderately or vigorously active for 90 minutes per day (per Canada Physical Activity Guide (2002) recommendations) and this trend was seen across rural, urban and Aboriginal communities (Standing Committee on Health 2007). The activity levels reported for the Aboriginal youth in this study suggest that nearly half were not meeting international PA recommendations. While data regarding physical activity in Canadian Aboriginal peoples is generally limited (Young and Katzmarzyk 2007), previous research has reported that physical activity levels of Aboriginal youth are inadequate (Bernard et al. 1995; Downs et al. 2008; Hanley et al. 2000; Ho et al. 2008; Katzmarzyk 2008; Ng et al. 2006; Seto et al. 2006; Statistics Canada 2004; Young and Katzmarzyk 2007). The First Nations Regional Longitudinal Health Survey (RLHS), for example, reported that less than half of Aboriginal youth (aged 12 through 17) accumulate sufficient (i.e., at least 30 minutes) physical activity on 5 or more days of the week and that an even greater proportion of children (9 to 11 years) do not participate in adequate moderate to vigorous physical activity (Seto et al. 2006). Moreover, low physical activity levels typically coincide with poor physical fitness levels (Hanley et al. 2000; Ho et al. 2008; Horn et al. 2001). In 2006, Ng et al. found that less than half (i.e., only 49%) of Cree children (9-12 years) from Quebec were sufficiently physically active for health benefits and an even greater percentage (i.e., 83%) had very poor physical fitness levels (e.g., below the 20th percentile) (Ng et al. 2006). Two other reports have served to enhance our knowledge of the physical activity behaviors in Canadian Aboriginal youth: Bernard et al. (1995) reported that Cree youth were physically active, on average, less than three (2.7) times per week and a second report indicated that the prevalence of sedentary behavior (20 h+/week) among a national sample of off-reserve Aboriginal adolescents (12-17 years) was 65.8% (Katzmarzyk 2008). In conjunction with the present findings, these data suggest an urgent need exists to promote physical activity in Canadian Aboriginal youth.

When physical activity behaviors of Aboriginal boys and girls were examined, activity energy expenditures (i.e., KKDs) were higher in Aboriginal boys than in Aboriginal girls, and a greater percentage of boys were meeting the recommendations for physical activity and television viewing. Findings from a national sample of off reserve Aboriginal youth (12-17 yrs) have similarly shown that Aboriginal boys had higher physical activity (1.3 ± 0.3 KKD) than Aboriginal girls (0.9 ± 0.2 KKD) (Katzmarzyk 2008). It has been noted in the literature that boys are more active than girls at all ages during the circumpubertal years (Thompson et al. 2003). However, since girls typically mature two years earlier than boys, it is possible that lower physical activity levels reported in girls, when compared to boys of similar chronological ages, could be attributed to an earlier age of maturation (Sherar et al. 2007; Thompson et al. 2003). When data from Aboriginal youth in the present study were adjusted for age, biological age, height and body mass, results showed that boys were more active than girls, and a greater proportion of girls compared to boys reported watching T.V. for two or more hours per day. Previous work suggests that Aboriginal boys spend more time playing video games than girls (7.3 h/wk vs. 4.2 h/wk) (Katzmarzyk 2008), and that the prevalence of sedentary behavior (20 h+/week) is significantly higher (i.e., 71.7%) in Aboriginal boys; versus (59.0%) girls (Katzmarzyk 2008). However, these students did not account for biological maturation. Although the present study did not detect any differences in TV viewing between maturity categories, a notable decline in TV viewing was reported in

Aboriginal girls at PHV, and a significant difference in the proportion of girls and boys meeting recommendations for TV viewing was seen at PHV. It is difficult to provide an explanation for these findings; thus, further exploration of the effects of biological maturation on sedentary behaviors such as T.V. viewing, may be worthwhile.

A recent review of American studies suggests that Aboriginal people experience several barriers to living a physically active lifestyle, including safety concerns, lack of facilities and programs and poor infrastructure (Coble and Rhodes 2006). Barriers within the school environment, such as body related issues related to physical education (P.E.) class in young Aboriginal women, may lead to higher dropout rates in P.E. (Coble and Rhodes 2006). While these barriers are noteworthy, it is likely that they would be very similar to those experienced by Caucasian youth. Therefore, further research should explore the correlates and determinants of physical activity in Aboriginal boys and girls, to establish a greater understanding of what interventions could enhance physical activity in this ethnic population. Socio-economic and socio-cultural factors, for example, may have greater implications for physical activity behaviors among the Aboriginal population. Research has shown that higher education and income are both associated with lower odds of being physically inactive (Katzmarzyk 2008) and data from the RLHS suggest that Aboriginal youth in lower income households (<10k) are more likely to never participate in physical activity compared to higher income households (≥50k) (10 vs. 4.2%) (Statistics Canada 2004). Given that poverty is pervasive in many Canadian Aboriginal communities, socio-economic status may be a contributing factor to physical inactivity. It is also possible that socio-cultural factors, such as beliefs about exercise for the purpose of improving one's own fitness and health, may act as a barrier to the adoption of regular physical activity. Furthermore, social support is an important factor in youth physical activity (Humbert et al. 2005), and a high prevalence of physical inactivity and lack of vigorous activity in First Nations adults has been noted in earlier studies (Ho et al. 2008).

There are a few limitations to this study worth noting. Our assessment of physical activity relied on self-report in the calculation of the activity scores and activity energy expenditures (KKDs) and consequently, may not be as accurate as objective measures such as accelerometry. However, both the PAQ-C/A and the MAQ-A have demonstrated good internal consistency and validity with several other evaluations of physical activity (Crocker et al. 1997) and, for the purposes of this study, were considered to be appropriate by the researchers and school teachers involved in this study. In addition, the use of the MAQ-A to assess physical activity is beneficial in that it includes culturally diverse activities (e.g., Aboriginal dancing), and many studies of physical activity in Aboriginal peoples to date have not included cultural based activities or measured PA using questionnaires specifically developed for use in Aboriginals (Kriska et al. 1990). Furthermore, because the MAQ-A provides an estimate of activity energy expenditure through physical activity, it allowed for the calculation of the proportion of Aboriginal youth meeting physical activity recommendations.

Other limitations include the lack of consideration for socioeconomic status in our study. The implications of not doing this may have affected our overall results, as Canadian data show that SES can be positively associated with physical activity levels (Katzmarzyk 2008). Perhaps the major limitation of this study is the time elapsed between data collection for the Aboriginal study (2005-06) and the PBMAS (1991-1997). Given that physical activity levels may have declined over the past decade as a result of increasing technologies and a more sedentary environment, it is possible that the lack of differences in the PA levels among ethnicity groups is, in part, due to utilizing a sample collected 10 years earlier for comparison. The lack of information on the number of youth who received information about the study but declined, and sample size limitations, which necessitated collapsing all Aboriginal youth (urban/rural/reserve) into the same group for analyses, are also limitations of this study. Finally, although our results were adjusted for biological maturity, a longitudinal study would be required to determine how physical activity in the two ethnic groups would change over time and the implications of our findings in terms of health risks can only be speculated.

Recent research has shown that Aboriginal youth have greater prevalence of overweight/obesity and total and central adiposity than their Caucasian peers (Anderson et al. 2010), which may be associated with physical inactivity. However, findings from the current study suggest that physical activity levels in girls do not significantly differ and thus may not be associated to differences seen in adiposity and obesity levels between Aboriginal and non-Aboriginal girls. Nonetheless, because ethnic differences in boys emerged, ethnic and sex specific recommendations, programs and policies for physical activity may be necessary.

It is hoped that the results of this study will contribute to future research identifying correlates and determinants of physical activity among Aboriginal boys and girls for the development of PA guidelines, programs and policies, and effective prevention models. Longitudinal studies are also necessary to explore whether ethnic and sex differences in physical activity behaviors could contribute to varying chronic disease rates in this population.

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Legends to Figures

FIGURE 1. Physical activity scores (where 1 is low; 5 is high) in Aboriginal and Caucasian boys and girls; where independent t-tests were used to detect differences between ethnic groups (* $P<0.05$ and ** $P<0.01$).

FIGURE 2. Physical activity in Aboriginal youth by maturity category analyzed by Chi-square and Fishers Exact test.

FIGURE 3. TV viewing in Aboriginal boys and girls by maturity category analyzed by Chi-square and Fishers Exact test.

TABLE 1. Physical characteristics of subjects (N = 409) by ethnicity and sex at each chronological age and biological age band.

Chronological Age (yr)	n		Height (cm)		Body Mass (kg)		Biological Age (Yr from APHV)	n		Height (cm)		Body Mass (kg)	
Boys	**Ab**	**Cn**	**Ab**	**Cn**	**Ab**	**Cn**		**Ab**	**Cn**	**Ab**	**Cn**	**Ab**	**Cn**
8	3	1	134(1.7)	128.4(--)	37(8.7)	32(--)	-5	1	0	134 (--)	--	33 (--)	--
9	4	4	131(11.0)	142(6.0)*	33(5.3)	33(3.4)	-4	6	5	130 (6.6)	137 (5.1)*	32 (7.1)	33 (2.2)
10	16	3	143(5.5)	147(7.9)	40(8.5)	35(4.1)	-3	18	8	143 (3.2)	147 (5.1)*	38 (5.5)	39 (6.1)
11	14	13	151(7.3)	147(3.8)	49(13.5)	39(4.7)*	-2	18	11	149 (3.3)	149 (4.0)	51 (11.8)	38 (4.0)*
12	15	20	154(8.3)	153(5.8)	53(13.7)	40(6.5)*	-1	13	30	158 (5.7)	156 (6.8)	54 (12.3)	46 (11.7)*
13	6	16	157(9.9)	158(6.5)	57(20.5)	49(11.7)*	0	6	14	164 (4.6)	163 (8.6)	53 (10.2)	49 (8.7)
14	7	21	175(7.5)	170(8.2)	62(9.3)	57(10.8)	1	13	15	174 (6.4)	173 (6.9)	64 (11.0)	59 (9.1)*
15	15	9	172(8.7)	171(7.2)	66(21.6)	57(8.7)*	2	12	8	177 (5.2)	178 (6.3)	68 (10.6)	67 (9.8)
16	8	5	180(11.3)	181(4.4)	81(31.6)	78(12.3)	3	5	6	186 (3.6)	179 (7.3)*	108(27.6)	78 (15.7)*
17	5	5	179(7.4)	179(10.2)	68(6.8)	76(14.4)*	4	6	0	183 (5.3)	--	79 (5.7)	--
TOTAL	93	97											
Girls	**Ab**	**Cn**	**Ab**	**Cn**	**Ab**	**Cn**		**Ab**	**Cn**	**Ab**	**Cn**	**Ab**	**Cn**
8	3	2	139(5.5)	141 (11.0)	43(13.9)	40 (16.1)	-5	0	0	--	--	--	--
9	2	3	140(.8)	148 (9.1)*	48(13.5)	43 (11)	-4	0	1	--	132 (--)	--	28(--)
10	7	8	143(5.3)	144(4.1)	41(9.0)	34 (4.8)*	-3	2	0	136 (2.5)	--	35 (2.9)	--
11	11	8	150(5.8)	150 (5.2)	43.5(9.1)	44.1(10.7)	-2	6	8	140 (4.0)	145(4.1)	43 (12.1)	39 (9.9)
12	16	20	158 (8.0)	155 (9.8)	57(23.4)	45(11.3)*	-1	11	15	147 (4.1)	149 (9.1)	42 (7.4)	39 (10.7)
13	20	26	160(4.6)	160(5.7)	58(11.9)	53(8.5)	0	14	13	154 (4.5)	155 (5.5)	43 (7.1)	45 (7.0)
14	23	22	163(4.7)	161 (4.0)	63 (13.4)	54(10.2)*	1	25	28	159(4.0)	161 (6.5)	56 (9.4)	52 (10.7)
15	18	14	164(3.8)	163 (5.8)	64(12.4)	58(13.6)	2	33	28	164 (4.1)	161 (4.2)	67(14.0)	56 (9.2)*
16	4	2	167(3.7)	169 (10.0)	63(5.5)	57.8(4.0)	3	14	12	165 (4.1)	163 (6.0)	69(15.5)	58 (16)*
17	8	2	165(3.6)	171 (4.1)*	67(12.0)	76(17.7)*	4	7	2	167 (3.2)	174 (0.0)*	69(11.4)	61 (3.6)*
TOTAL	112	107											

Values are presented as means (SD), where SD = standard deviation.
Ethnic differences between Aboriginal (Ab) and Caucasian (Cn) analyzed by ANOVA where * indicates significance at the 0.05 level.

TABLE 2. Descriptive characteristics and physical activity behaviors of Aboriginal youth (N = 238) aligned by maturity category.

	Maturity Category					
	Pre-PHV		**PHV**		**Post-PHV**	
	SEX					
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
n	59	30	8	21	52	68
Physical characteristics						
Height (cm)	145.6 (1.1)	147.0 (1.6)	158.1 (2.0)^{j}	158.6 (1.2)^{j}	174.5 (0.9)$^{i\,k}$	164.0 (0.8)$^{**\,i\,k}$
Body mass (kg)	45.1 (1.8)	42.8 (2.6)	49.6 (5.0)	56.1 (3.1)	67.2 (2.1)$^{i\,k}$	64.7 (1.8)$^{i\,k}$
BMI (kg/m^2)^{a}	20.4 (0.1)	20.6 (0.2)	21.4 (0.1)	21.5 (0.1)^{j}	22.9 (0.1)	23.2 (0.1)$^{*\,i}$
Chronological age (yrs)	10.7 (0.2)	10.6 (0.2)	12.6 (0.3)^{j}	12.6 (0.2)^{j}	15.3 (0.2)$^{i\,k}$	14.8 (0.2)$^{i\,k}$
Behavioral variables						
Physical activity level (KKD)^{a}	5.9 (0.7)	3.5 (0.9)*	6.9 (1.8)	4.4 (1.1)	9.1 (1.1)^{i}	5.8 (0.9)^{*i}
Physical activity level (PAQ-C/A score)^{a}	2.8 (0.1)	3.0 (0.1)	3.1 (0.2)	2.8 (0.1)	2.8 (0.1)	2.6 (0.1)^{i}

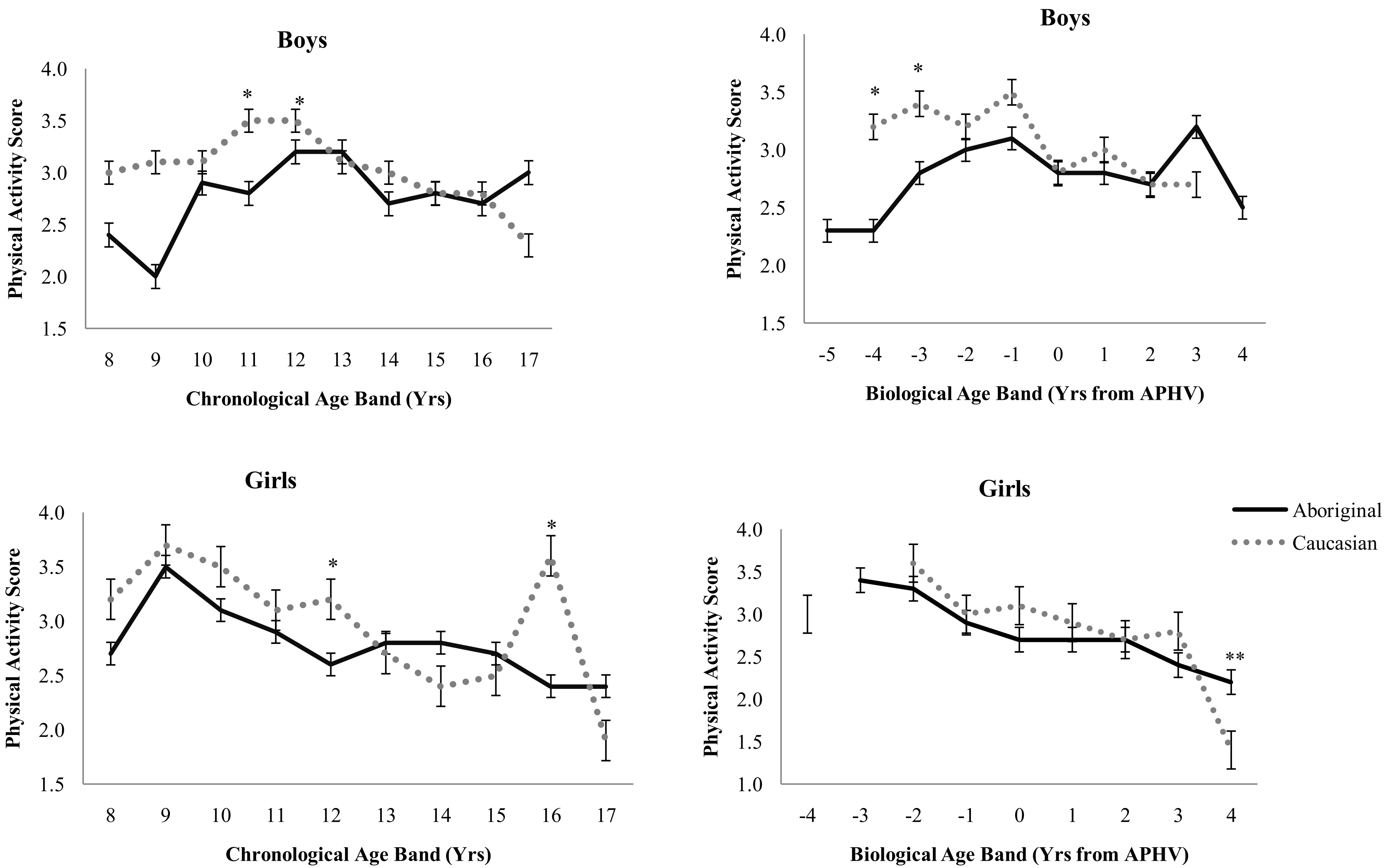
All values presented as means (SE).

^{a} Data are adjusted for height, body mass and chronological age.

PHV, peak height velocity; BMI, body mass index; KKD, kilocalories per kilogram of body weight per day (international recommendations ≥ 8KKD).

Sex differences analyzed by ANCOVA, where * indicates significance at the 0.05 level and **indicates significance at the 0.01 level.

Maturity differences detected using ANCOVA and LSD post hoc, where *i* indicates significance from pre-PHV to post-PHV; *j* indicates significance from pre-PHV to PHV; *k* indicates significance from PHV to post-PHV, at the 0.05 level.



Boys
Physical Activity Score
Chronological Age Band (Yrs)
Boys
Physical Activity Score
Biological Age Band (Yrs from APHV)
Girls
Physical Activity Score
Chronological Age Band (Yrs)
Girls
Physical Activity Score
Biological Age Band (Yrs from APHV)
Aboriginal
Caucasian

FIGURE 1.

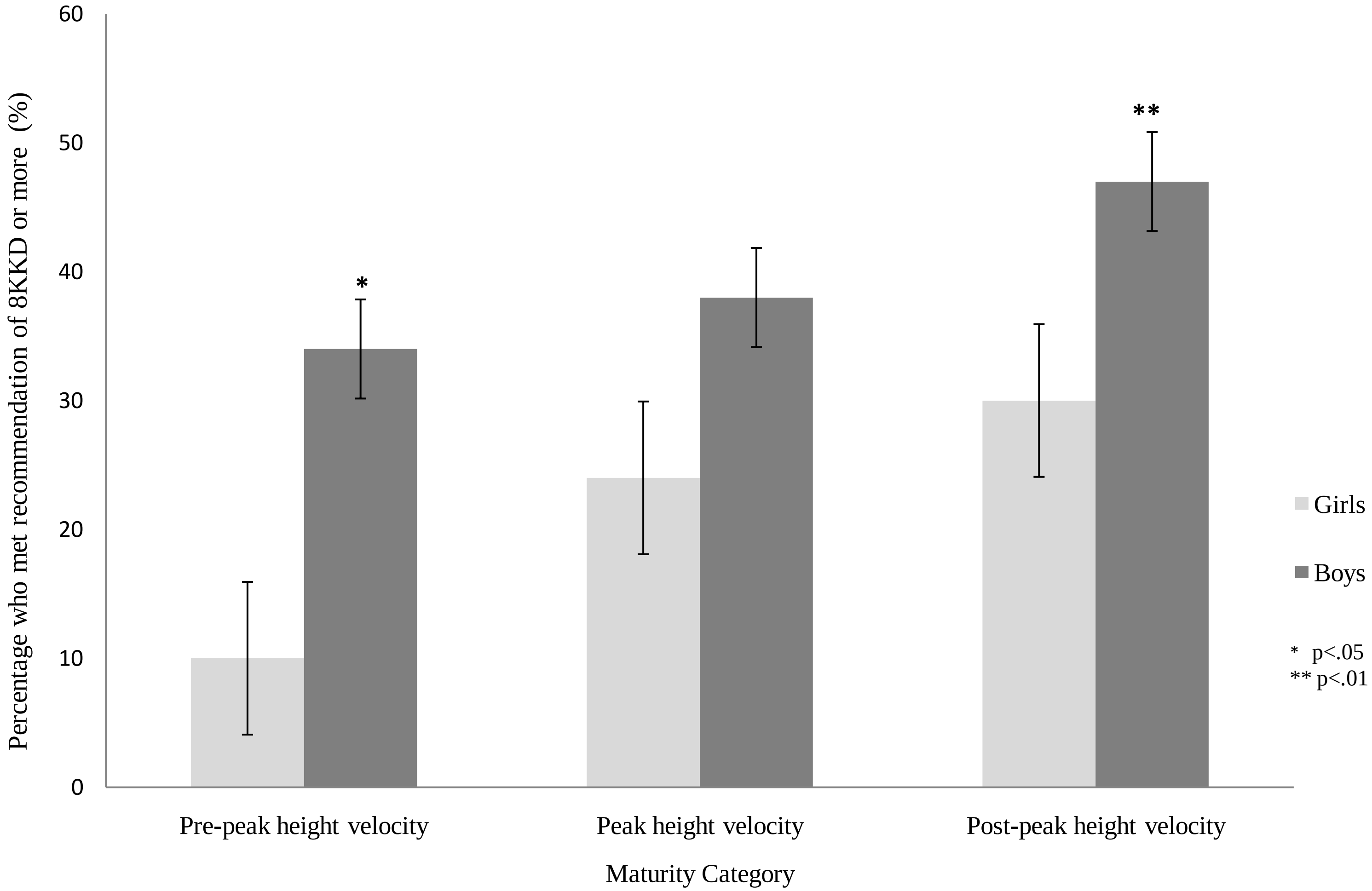
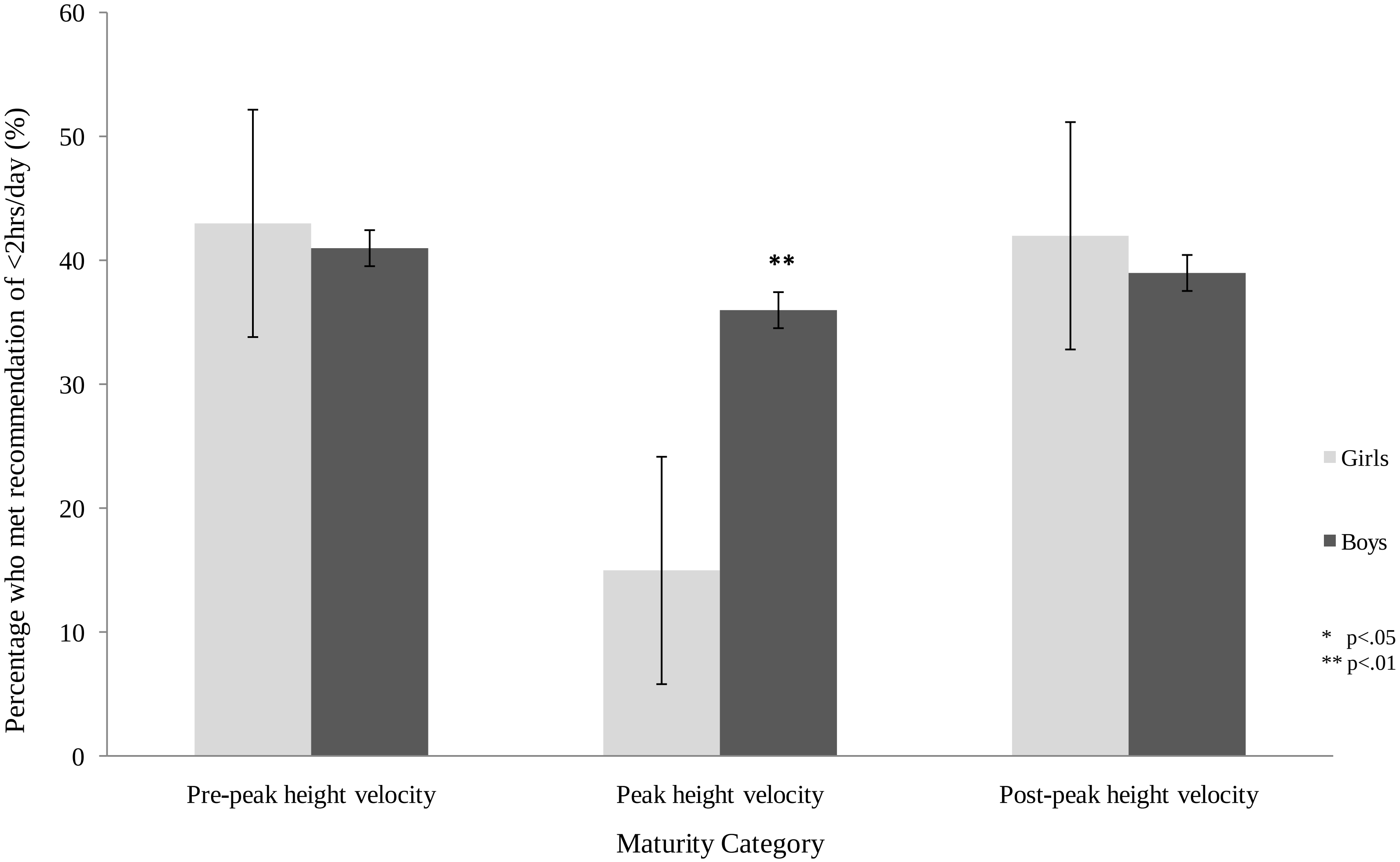

Percentage who met recommendation of 8KKD or more (%)
60
50
40
30
20
10
0
*
**
Pre-peak height velocity
Peak height velocity
Post-peak height velocity
Maturity Category
Girls
Boys
* p<.05
** p<.01

FIGURE 2.



60
50
40
30
20
10
0
Percentage who met recommendation of <2hrs/day (%)
**
Pre-peak height velocity
Peak height velocity
Post-peak height velocity
Maturity Category
Girls
Boys
* p<.05
** p<.01

FIGURE 3.

6

Paper III: Relationships of physical activity and diet with adiposity in Aboriginal youth

Canadian Journal of Public Health (in progress)

ABSTRACT

Purpose: The purpose of this study was to investigate relationships of physical activity (PA) and diet with adiposity in Canadian Aboriginal youth. **Methods:** 108 boys and 104 girls (8 – 17 yrs) were recruited. Activity energy expenditures (AEE) in kilocalories per kilogram of body weight per day (KKD) were derived from the Modifiable Activity Questionnaire for Adolescents (MAQ-A). Energy intakes were estimated using a 24-h dietary recall and multiple-pass interview approach. Height, body mass and waist circumferences were measured and ages at peak height velocity (APHV) predicted. Dual energy x-ray absorptiometry (DXA) indicated relative total body (TBF) and trunk fatness (TF). Descriptives (Means ± Standard Error) with independent t-tests, analysis of covariance (ANCOVA) (covariates chronological age, biological age, height, body mass) and multiple linear regressions were run in boys and girls separately to examine relationships of physical activity and diet, with waist circumference (WC), TBF and TF. **Results:** In final adjusted models, energy intake (EI) was a predictor of TBF and TF, T.V. viewing was a predictor of TF and AEE was a predictor of WC in girls ($P<0.05$). In boys, AEE was a predictor of TF ($P<0.05$). Although energy intake was the sole dietary variable related to the adiposity measures, descriptives showed eating behaviors (i.e., consumption of fruits and vegetables, sugar sweetened beverages, and other foods) of the Aboriginal youth were less than optimal when compared to guidelines. **Conclusion:** Although cross-sectional, these results suggest that physical activity is related to adiposity in Aboriginal boys and girls, perhaps more so in the central region. While findings from this study showed EI was the sole variable related to adiposity, the promotion of healthy eating in this population is warranted. Longitudinal research is needed to confirm the role of PA and diet on adiposity development in this population. **Key words:** ABORIGINAL YOUTH, ADIPOSITY, DIET, DXA, MULTIPLE REGRESSION, PHYSICAL ACTIVITY, SUGAR-SWEETENED BEVERAGE, TV VIEWING.

Introduction

Childhood obesity has become an epidemic, to the extent that experts fear that children today will be the first generation to have poorer health outcomes and a shorter life expectancy than their parents (Olshansky et al. 2005). Overweight and adiposity are highly prevalent among Canadian Aboriginal youth (Downs et al. 2008; Katzmarzyk 2008; Willows 2005) and consequently, this population is prone to the early development of the metabolic syndrome (MetS) and type 2 diabetes (T2D) (Dean 1998; Horn et al. 2007; Young et al. 2000). A number of factors have been implicated in the recent childhood obesity trend (Willows 2005), including the underlying components of energy balance, physical activity and dietary intake (Tremblay and Willms 2000). Over the past few decades, physical activity and dietary behaviors have changed dramatically as a result of increased reliance on technology; a change that has impacted the lifestyles of all Canadians, particularly children. Recent objective data indicate that the majority of Canadian youth (5-19 yrs) engage in nearly 6 hours of screen time (i.e., <2 hours of watching T.V., DVDs, or playing videogames) daily (Active Healthy Kids Canada 2009), with the majority (i.e., 87%) accumulating insufficient physical activity for maintenance of health (Active Healthy Kids Canada 2009). Recent reports further show that physical fitness levels in Canadian youth have significantly declined over the past few decades, regardless of age and sex (Tremblay et al. 2009). National data also indicate that there have been simultaneous increases in the consumption of fast foods, pre-packaged foods, soft drinks and candy (Garriguet 2008) and decreases in the consumption of fruits and vegetables in Canadian children and adolescents (Perez 2002). While the above information has been obtained mainly from Caucasian youth, data from Aboriginal youth also suggest physical inactivity and poor eating patterns are prominent (Garriguet 2008; Katzmarzyk 2008; Ng et al. 2006; Willows 2005), and may explain the rise in childhood obesity rates over the past few decades (Tremblay et al. 2000).

Although research investigating the relationships between physical activity, diet and adiposity in youth is generally inconclusive (Patrick et al. 2004), there is some evidence to support a association between lifestyle and overweight and obesity in Canadian youth (Janssen et al. 2004; Shields 2005). For example, higher physical activity levels in youth have been associated with lower risk for obesity, while sedentary activities (such as watching TV) have been associated with greater risk for overweight and obesity (Janssen et al. 2004). Findings have also indicated that Canadian youth who eat five or more servings of fruit and vegetables a day are substantially less likely to be overweight or obese than those whose consumption is less frequent (Shields 2005). Canadian studies of Aboriginal (First Nations, Métis and Inuit) youth have reported similar findings (see Table 1). Bernard and colleagues (1995), for example, showed that overweight was associated with poor diet, low physical activity, and high TV viewing in Cree schoolchildren. In 2000, Hanley and associates found significant inverse associations between overweight and TV viewing, fitness level, fiber intake and junk food consumption in Oji-Cree youth (10-19 yrs) from Ontario. Similarly, Horn and associates (2001) showed TV viewing was a predictor of adiposity among Aboriginal girls, and poor physical fitness and involvement in summer sports were correlates of adiposity among both boys and girls from the Mohawk community of Kahnawake. More recently, Downs et al. (2008) reported Cree children (9-12 yrs) with central adiposity (i.e., a waist circumference ≥ 85^{th} NHANES percentile) consumed fewer fruits and vegetables, had lower physical activity levels and lower physical fitness than those Cree children without central adiposity. While the above findings contribute to our understanding of the associations between lifestyle and adiposity, an investigation of these relationships using a more comprehensive approach to the assessment of adiposity would enhance the literature.

The purpose of this study was to explore relationships of physical activity and diet with adiposity in Aboriginal youth. Since biological maturity has been demonstrated to exhibit growth and maturation associated variation in the physical activity levels of growing children (Thompson et al. 2003; Sherar et al. 2007), the present study controlled for both chronological and biological age. It was hypothesized that when age, size and maturity, and their interactions were accounted for, physical activity and diet would be inversely related to adiposity (waist circumference, total body and trunk fatness).

Methods

Participants

Three hundred and fifty-two self- identified Aboriginal youth (i.e., majority First Nations) from Saskatchewan, Canada, were recruited for this study. Approval was obtained from the University Research Ethics Board and the school principals and teachers. Assent to all procedures was received from each participant along with written consent from their respective parent/guardian(s). Additionally, each Aboriginal community involved provided verbal consent to have their youth participate in this research.

Procedures for recruitment and data collection for youth in this study have been described previously (Anderson et al. 2010). In total, 352 self-identified Aboriginal youth from 12 rural reserves and 4 small to mid-sized (i.e., population ≤ 250, 000) urban schools within central Saskatchewan, Canada, obtained consent to participate. Data collection took place over a 16 month period between 2004 to 2006 using standardized lab procedures.

Measures

Ethnicity. Ethnicity was self-identified based on responses to a question that provided three different ethnic categories (i.e., First Nations, Métis and Inuit). Additionally, one question asked participants to identify their tribal group (e.g., Cree, Mohawk, Ojibwa, etc.). Assistance from the parent or teacher accompanying the youth was provided if he/she could not respond to this question on their own.

Geographic location was derived from the participants' current residence and classified as either urban or rural based on the school they were attending using the 2002 Canadian Census dictionary. For the purposes of this study, all youth from reserve schools were located in rural areas, and were therefore considered together in one category, hereinafter referred to as "reserve" in this paper.

Age and Biological Maturity. Participants were defined by chronological and biological age. Chronological age was determined to decimal age value by subtracting birthdate from the assessment date and truncated using 1 year intervals (e.g., whereby the 15-year age group included data between 14.5 and 15.49 years). In addition to height, age and weight, sitting height was used to predict the age when peak height velocity (APHV) was likely to occur. Years from APHV, an indicator of biological maturity, was determined by subtracting the chronological age of the individual at the time of measurement from the APHV (Mirwald et al. 2002). A continuous measure for biological age was generated and truncated using 1-year intervals, for example, the -1 year from APHV group included observations between -1.49 and -0.50 years from APHV.

Physical Activity. The Modifiable Activity Questionnaire for Adolescents (MAQ-A) (Aaron et al. 1995; Kriska et al. 1990) was used to assess physical activity levels based on an estimate of physical activity energy expenditure. Additionally, a self report checklist to assess television viewing provided an indication of sedentary behavior.

The MAQ-A, developed to assess physical activity behavior in ethnic populations (Kriska et al. 1990), is a reliable and valid self-reported measure suitable for use in youth (Aaron et al. 1995). Designed for easy modification to maximize its feasibility and appropriateness in a variety of minority populations (Kriska et al. 1990), the MAQ-A has been used in previous Canadian Aboriginal studies (Hanley et al. 2000). Coble et al (2006) suggest that physical activity preferences in Aboriginal youth have moved away from traditional activities to more sport and lifestyle activities such as baseball; therefore, the MAQ-A was modified for this study to include a menu of both traditional, culturally appropriate and sport/lifestyle activities. Participants identified all organized and non-organized leisure activities performed over the past 4 weeks and classified them as light, moderate, or vigorous intensity. For each activity listed, the product of the metabolic cost (METs), average duration in minutes, and frequency for the week was calculated and divided by the number of days in the week. The value of each activity was summed to yield total KKD (kilocalories per kilogram of body weight per day), with greater KKDs indicative of higher physical activity levels. Appended to the MAQ-A was a self-report checklist to assess time spent on weekdays and weekends watching television and derive a screen time summary score (where a higher score was indicative of greater screen time). For our analyses, physical activity data were dichotomized using an international cut-point of 8 KKD, which is associated with optimal childhood health and development (Craig et al. 1999), while television (T.V.) data were dichotomized using a cut-point of 2hr/day, as per commonly cited recommendations (American Academy of Pediatrics 2007). Although the lack of formal validation for our T.V. viewing measure is an acknowledged limitation, previous studies have reported that young children (Robinson 2001) can provide accurate self-reports of their television watching.

Dietary behaviors. Information regarding the dietary practices of the participants was gathered using semi-structured 24-hour dietary recalls using a multiple-pass interview technique with three stages (Goran 1998). Plastic 3-D food models, measuring cups and spoons were used to determine portion sizes and increase accuracy of the data. Reported energy intake using a multiple pass interview approach with 24-hr dietary recalls has compared well with activity energy expenditure in youth (Goran 1998) and is a valid method for assessing dietary intake among Aboriginal youth (Weber et al. 2004). Data obtained from the 24-hour recalls was analyzed for energy and nutrient content using Food Processor SQL for Window (Food Processor SQL, version 8.5, ESHA Research, 2001, Oregon), a program which enables the use of both the USDA Handbook 8 (USDA 1999) and the Canadian Nutrient File (Health Canada 2005). Moreover, the Food Processor database includes more than 20,000 food items, including specialty, ethnic and fast foods, and allows other food items to be entered from recipes, making it suitable for use with the Aboriginal population.

Dietary variables reported in this analysis included estimated energy intake per day (kilocalories/day); fruits and vegetables (servings per day); sugar-sweetened beverage consumption (milliliters); and “other” foods (servings of sweets, desserts, fats and oils per day). Estimated total energy intake (EI) was calculated by the Food Processor program. The 2007 *Eating Well with Canada's Food Guide: First Nations, Inuit and Métis* was used to determine number of daily servings of fruits and vegetables (FV); the FV category included baked or roasted potatoes but excluded french-fries. Sugar-sweetened beverages (SSB) were defined as any beverages that contained added sugar, including soft drinks, sport drinks, drinks made from crystals or flavored syrup, punches less than 50% real fruit juice, liquid shakes, hot chocolate and iced tea. Thus, any drink that was not 100% fruit juice or that was considered to be “empty calories” lacking significant amounts of beneficial nutrients was included in this definition. Milk and milk-based drinks (i.e., chocolate milk was counted in the milk and alternatives food group) as well as zero calorie (e.g., diet soda) drinks were considered an exception and were therefore excluded. “Other” foods (OF) constituted foods that were high in sugar, fats and oils and were not typically included in the main food groups (i.e., Meat and alternatives; fruits and vegetables, etc.) as per *Canada’s Food Guide* (Health Canada 2007). Any beverage considered to be a SSB was coded only as SSB (and not also as an “other” food) for the purposes of our analyses. The above diet variables were chosen for this research since is more fruitful to investigate a range of eating patterns than energy intake alone (Patrick et al. 2004).

Body Composition. Participants wore light clothing with their shoes removed for all anthropometric measurements. Weight was measured in duplicate to the nearest 0.1 kg using a Tanita Solar (HS – 301) electronic scale. Height and sitting height were measured in duplicate to the nearest millimeter using a Harpenden Stadiometer (Holtain Ltd). Sitting height was calculated by subtracting the height of a standardized box from the participants’ height. Waist circumference (WC) was measured in duplicate (or in triplicate if the difference between the first two measurements exceeded 4 mm) with a flexible steel tape directly on the skin, at the level of the narrowest point between the lower costal border and the iliac crest at the end of a gentle expiration. If there was no point of noticeable narrowing, WC was measured midway between the two landmarks (Norton et al. 1996). The mean of all WC measurements was recorded.

Total body scans were completed on all participants using dual x-ray absorptiometry (DXA) technology (Hologic Discovery 4500 *Wi*; Waltham, Mass.). Each scan lasted around 7 minutes, while the participant remained still, lying supine on the scan bed. Participants wore loose fitting clothing with all metal objects (jewelry, belts, etc.), socks and footwear removed. Standardized procedures were followed and a single nuclear medicine technician performed and analyzed all scans for consistency. Regional soft tissue mass was assessed using the standardized (i.e., manufacturer) regions of interest. Relative measures for total body fatness (TBF) and trunk fatness (TF) were calculated as 100 times the ratio of total body fat and trunk fat mass to total body mass, respectively.

Statistical Analyses

Distributions of continuous variables were assessed for normality and descriptive results are summarized as means ± standard error of mean (SEM) unless otherwise specified. Heights and weights were compared to sex-specific CDC reference standards by chronological age. Independent t-tests were used to examine age band differences in all continuous variables in boys and girls. Analysis of covariance (ANCOVA) was used to test for group differences (covariates: height, weight, age at test and biological age). Bivariate correlations and 2x2x3 ANCOVA (2 sex x 2 PA x 3 diet groups) were run to explore relationships between physical activity, diet and adiposity. As sex differences in body composition and lifestyle behaviours can be profound during the circumpubertal years (Malina and Bouchard 2004), sex-specific statistical models were built. PA was dichotomized into two groups using 8 KKD as a cut-point (Craig et al. 1999); each diet variable was divided into three equal groups using the 25^{th}, 50^{th} and 75^{th} centiles to represent high, medium and low consumption. Sex specific multiple linear regression models with total body fatness, trunk fatness and waist circumference as dependent variables were used successively to evaluate the effects of physical activity and diet variables on adiposity. Multiple stepwise regression was used to test independent variables (i.e., KKD; EI; SSB; FV; OF; TV category) on measures of adiposity. Age at test, biological age, height and weight were entered into the model as control variables in the first model. For the second model, forward entry determined which physical activity and diet variable predictors were entered into the model. All 2-way interaction terms for variables remaining in steps 1 and 2 were forward entered into step 3. The significant variables were tested in a final model using a significant criterion for forward entry set at $P < 0.05$. All analyses were made using SPSS (Version 16.0, Chicago, IL) with statistical significance set at a level of $P < 0.05$.

Results

Of the 352 participants recruited for this study, 339 Aboriginal boys (n = 166) and girls (n = 173) from urban and reserve schools across Saskatchewan participated. However, for the purposes of this analysis, complete data were required, and 212 youth met these criteria (108 boys and 104 girls). Eighty-six percent self-identified as First Nations (majority Cree) while the remaining 14% self-identified as Métis. Descriptive characteristics (i.e., heights and weights) are displayed in Figure 1. Data at each chronological age and biological age band are displayed by sex in Table 1. On average, girls were older (13.9 yrs vs. 13.5 yrs, respectively; $P>0.05$) and more mature (1.4 yrs APHV vs. 0.4 yrs APHV, respectively; $P<0.05$) in comparison to boys. The heights and weights for boys and girls in this study were within normal reference standards (CDC reference) across all chronological ages (Figure 1). Boys were taller ($P>0.05$) and lighter ($P>0.05$) when compared to girls (i.e., 161.2 cm vs. 159.7 cm for height and 56.5 kg vs. 57 kg for weight, in boys versus girls, respectively); when adiposity measures were compared at each biological age band, significant sex differences emerged post-PHV (i.e., $\geq$ 0 yrs APHV), particularly for TBF and TF (Figure 2 shows sex-specific patterns for boys and girls). At PHV (i.e., 0 yrs APHV) onwards, boys had a tendency to have decreased TBF, while the reverse (i.e., an increase in TBF) was seen in girls. Similar trends (with girls staying the same or increasing, while boys decreasing, following PHV) were seen for percentage trunk fatness. Overall, TBF and TF did not change significantly with increasing biological maturity in girls; however, it did significantly decline with increasing maturity in boys ($P<0.05$). At all biological ages, boys had lower TBF and TF (Figure 2); however, no significant sex differences were seen until PHV had been attained. A significant difference between boys and girls was seen at -1 yr APHV for waist circumference ($P<0.05$).

When data from the entire sample of Aboriginal youth was explored by sex group, results showed adjusted AEE for girls (4.8 KKD) was significantly lower in comparison to boys (7.3 KKD) ($P<0.05$). In contrast, analyses of the dietary data from the overall sample showed no significant differences between boys and girls, with the exception of a difference in energy intake. Mean servings of fruits and vegetables were comparable at 2.4 in girls versus 2.6 in boys ($P>0.05$); similarly, consumption of SSB (546mL for girls, 719 mL for boys; $P>0.05$) and other foods servings (5.0 servings for girls, 6.1 servings for boys; $P>0.05$) in boys and girls did not differ. However, a significant sex difference was seen in energy intake (1861 kcal in girls vs. 2383 kcal in boys; $P<0.05$). When proportions were compared, chi-square showed 32.4% of girls vs. 44% of boys did not meet the international recommendation of 8 KKD ($P <0.05$), and the majority of boys and girls were not meeting the requirement for FV (i.e., 9.7% of girls vs. 8.2% of boys were not meeting Canada Food Guide recommendations; P>0.05).

Mean adjusted activity energy expenditures (KKD), servings of fruits and vegetables, consumption of sugar sweetened beverages and consumption of other food servings are presented by sex and biological age in Figure 3. At pre- PHV, a significant sex difference (i.e., in number of servings of other foods) emerged (i.e., at -1 yr APHV) (P<0.05). At post-PHV (i.e., ≥0 yrs APHV), sex differences in other dietary variables were significant (i.e., SSB, FV, OF); however, no other differences in the dietary behaviors of girls and boys were observed (P>0.05). Estimated energy intakes, for example, varied by sex at PHV and 2 yrs APHV (P<0.05), while activity energy expenditures, on the other hand, were consistently higher in boys across all biological ages; however, these differences were significant only at 2 yrs APHV (Figure 3).

Results from ANCOVA showed that in both boys and girls, activity energy expenditures (KKDs) were inversely related to adiposity measures (i.e., WC in girls and TF in boys (P<0.05)). Final multiple regression models are presented in Tables 2 through 4. Results indicate that in girls, EI, weight and height were significant predictors of TBF in girls (best-fit model: R^2 =0.76, P<0.05). In girls, the same set of variables (i.e., EI, weight and height) were also significant predictors of TF with the addition of T.V. viewing (best-fit model: R^2 =0.78, P<0.05). Weight, height, biological age and activity energy expenditures (KDD) were predictors of waist circumference in girls in the final model (best-fit model: R^2 =0.92, P<0.05). Results from final adjusted models in boys showed age at test, height and weight were predictors of TBF (best-fit model: R^2 = 0.62, P<0.05) and WC (best-fit model: R^2= 0.89, P<0.05). Age at test, KKD, height and weight were predictors of trunk fatness when all adjusted variables were entered into the model (best-fit model: R^2 =0.64, P<0.05). No dietary variables were significant in these models for boys. No evidence of confounding or collinearity was detected in the sex specific models.

Discussion

The purpose of this investigation was to examine relationships of physical activity and diet with adiposity (waist circumference, total body and trunk fatness). The main findings suggest that physical activity may have an important role in the development of adiposity, perhaps more so in the central region.

The boys and girls in this study had mean heights and weights that were similar to reference norms, suggesting their growth was compatible with normal, healthy youth. Boys had lower total body fatness than girls at all biological ages, with the most notable sex differences observed after attainment of peak height velocity. For example, total body fatness in boys began to decrease just prior to PHV, while total body fatness remained the same until after PHV in girls. Similar sex-specific patterns were seen for trunk fatness (see Figure 2); however, minimal sex differences were seen in waist circumference. These findings are in agreement with those reported by Mundt et al. (2006), who conducted a similar (Caucasian) study and noted sex differences after adjusting for biological maturity.

The physical activity and dietary behaviors of the Aboriginal youth in this study were less than ideal when compared to current guidelines. The majority of youth did not attain the recommended level of daily physical activity; furthermore, consumption of sugar sweetened beverages and “other” foods was high and fruit and vegetable intake was low (mean intake in both boys and girls was less than 3 servings daily). These results support those noted previously in the literature. Downs et al. (2008), for example, similarly showed that the vast majority (i.e., 83.7%) of Cree youth (9-12 yrs) ate less than 3 fruits and vegetables per day; Horn et al. (2001) showed that T.V. viewing was prevalent in Mohawk youth (10-19 yrs); and Katzmarzyk (2008) recently showed that physical activity levels in Canadian Aboriginal youth were sub-optimal. There is also evidence to suggest that many Aboriginal youth consume too many “other” foods, too much sugar sweetened beverage and too few fruits and vegetables (Shields 2005). These findings suggest that the physical activity and dietary behaviors of Aboriginal youth are not unlike those of Canadian youth in general, given that recent reports indicate that sedentary activities are highly prevalent and that physical activity and physical fitness levels have significantly declined (Shields 2005; Tremblay et al. 2009).

Sex differences were evident with girls attaining less physical activity and consuming less energy intake than their male counterparts. When activity energy expenditures (i.e., KKDs) were compared, mean KKDs were higher in boys (vs. girls) at all biological ages; similarly, boys reported higher energy intakes than girls, but like KKDs, these differences were significant only after attainment of PHV. Thus, sex differences in activity expenditures and energy intakes seemed to widen after the attainment of PHV. Mundt et al. (2006) found similar results across biological maturity ages using similar lifestyle variables (i.e., sugar drink intake and physical activity level) in a sample of Caucasian boys and girls.

The present study is unique because it is one of the first to assess physical activity and diet in relation to adiposity using DXA with a relatively large sample of Canadian Aboriginal youth. It brings to the fore an inverse relationship between physical activity and adiposity, independent of TV viewing time and other biological confounders, among them age and maturity. In girls, the relationship between physical activity and waist circumference persisted after controlling for height and weight, with a greater effect of physical activity in the participants with a higher waist circumference. A similar (inverse) relationship was seen in boys, only between physical activity level and measured trunk fatness. Although cross-sectional, these results suggest that higher levels of physical activity are associated with adiposity, perhaps more so in the central region.

While Kim and Lee (2009) suggest the role of regular physical activity in reducing abdominal obesity is unclear in a review of studies in youth, our findings, as well as others, show an inverse relationship between physical activity and adiposity. In 2004, Janssen and colleagues showed that overweight and obesity were associated with decreased physical activity participation and increased television viewing in a nationally representative sample of adolescents. In a recent study by Dencker and colleagues (2008), vigorous physical activity was found to be a significant correlate ($r = -0.35$, $P<0.05$) of DXA measured abdominal adiposity. In a large sample of French boys and girls (Klein-Platat et al. 2005), both structured physical activity (activities outside of school that amounted to more than 140 min per week) and sedentary activities (i.e., TV viewing), assessed via self-report questionnaire, were associated with waist circumference. In 2007, Ortega and colleagues found that physical inactivity in a large sample of Swedish youth was associated with a greater risk of being overweight and having a high risk waist circumference, after controlling for confounders. Although limited, related research with Aboriginal youth has reported similar relationships. For example, a study with Cree children with and without central adiposity showed that youth with central adiposity were more likely than those without central adiposity to have an inadequate physical activity level (Downs et al. 2008). Mitchell (2008) has also provided evidence of the important role of physical activity, particularly moderate to vigorous intensity, in improving insulin resistance and potentially preventing T2D in First Nations youth. Future research should explore varying intensities of physical activity and the association with total and central adiposity measures in age and maturity matched Aboriginal boys and girls.

Findings from this study did not support the proposition that diet is related to adiposity. These results are in agreement with conclusions of a previous cross sectional study which reported no significant relationship between BMI and sugar sweetened beverage consumption in adolescents (Mundt et al. 2006). In contrast, Downs et al. (2008) showed that sweetened beverage consumption was associated with increased waist circumference in Cree children (9-

12 yrs). While the present analysis has no evidence of systematic reporting bias, it is possible that this inconsistency in findings may be the result of reporting errors (Livingstone et al. 2004) or varying methodologies across the different studies.

There a few limitations of this study that should be noted. The reliance on self-reported data, for example, can produce bias, which may have resulted in a failure to detect differences in physical activity and diet with the MAQ-A and 24hr dietary recall. Objective measures of physical activity, such as pedometers or accelerometers, would have increased the precision of measurement in this study. Our assessment of physical activity relied on self-report in the calculation of the activity scores and energy expenditure (KKD) and consequently may not have provided data as accurate as objective assessment measures such as accelerometry. However, the MAQ-A has demonstrated good reliability and validity (Aaron et al. 1995), and 24- recalls have been shown to be a valid method for assessing dietary intake among Aboriginal youth (Weber et al. 2004); thus, the MAQ-A and 24hr-recall were deemed appropriate for this study. Additionally, there is a rapid increase in the ability of youth to self-report food intake from the age of 8 years onwards (Livingstone and Robson 2000) and reported energy intake using a multiple pass approach with 24-hr dietary recalls has compared well with activity energy expenditure in youth in previous work (Goran 1998). Although our results were adjusted for biological maturity, a longitudinal study would be required to establish cause and effect relationships. Other limitations include the lack of assessment for socioeconomic status (SES), as Canadian data have shown that SES can be positively associated with physical activity and diet (Raine 2004). The lack of information on the number of youth who received information about the study but declined (therefore participation rate cannot be determined) and sample size limitations, which necessitated collapsing all Aboriginal youth (First Nations/Métis/Inuit) into the same group for analyses, are also limitations of this study. Given this, questions regarding the effects of this admixture cannot be answered. We openly recognize that there is considerable diversity within the various Aboriginal populations in the geographic regions we examined. We are also aware that traditions and cultural activities of the communities investigated likely vary from one another.

In conclusion, this research suggests that low levels of physical activity, and perhaps excess T.V. viewing and excess energy intake, may lead to the development of adiposity in Aboriginal youth, independently of biological factors such as age and maturity. It is our hope that studies such as this one will initiate future work that will contribute to the development of effective and sustainable programs targeting physical activity as well as healthy eating for integration into Aboriginal schools, families and communities.

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TABLE 1. Canadian research on factors related to adiposity in Aboriginal youth

Authors	Title	Population (n)	Study Design & Measures	Summary
Bernard et al., 1995	Overweight in Cree schoolchildren and adolescents associated with diet, low physical activity, and high T.V. viewing.	Cree children and adolescents (grades 4/5 & 8/9) from James Bay, Quebec (144)	Cross sectional: BMI; questions on PA frequency and T.V. viewing; 24-hr dietary recall	OW subjects got less PA, watched more T.V. and consumed less F/V or milk products than their NW peers; total energy intake not evaluated
Hanley et al., 2000	Overweight among children and adolescents in a Native Canadian community: prevalence and associated factors	Oji-Cree youth (10-19 yrs) from remote community of Sandy Lake, Ontario (242)	Cross sectional: BMI; questions on T.V. viewing, submaximal fitness step test; 3 month FFQ & 24-hr dietary recall; body image questionnaire	OW children watched more T.V., had a lower fitness level and ate less fibre than NW children. T.V. viewing ≥5 hr/d associated with higher risk of OW; inverse relation between OW and healthy body image
Horn et al., 2001	Correlates and predictors of adiposity among Mohawk children	Mohawk children (elementary aged; mean 7.5 yrs) from Kahnawak`e, Quebec (198)	Longitudinal and cross sectional: BMI, WC, & subscapular skinfold (SSF); questions on demographics and lifestyle; run-walk fitness test	*Cross sectional*: 5+ hours/d of T.V. associated with 2.5 greater likelihood of being OB and having lower PF. Children obtain a high percent of energy from sugar, but no link to OW. T.V. watching is more closely related to SSF than to vigorous PA. *Longitudinal*: T.V. viewing is a consistent determinant of adiposity among girls.
Downs et al., 2008	Central adiposity and associated lifestyle factors in Cree children	Cree children (9 – 12 yrs) from Northern Quebec (178)	Cross sectional: BMI & WC; physical activity via pedometers; physical fitness 20 m shuttle run; 24-hr dietary recall	WC negatively correlated with pedometer step counts and shuttle run time; in children with CA, WC positively correlated with sweetened beverage intake. Odds ratio for CA for children consuming 3+ F/V per day was 0.43, for meeting recommended step counts was 0.45 and for relative fitness was 0.12.

Legend:
PA – physical activity; PF – physical fitness; CA – central adiposity; NW – normal weight; OW- overweight; OB- obesity; WC – waist circumference; T.V. – television; BMI – body mass index

TABLE 2. Boys and girls at each chronological age and biological age band.

Chronological Age (yr)	N	Biological Age (Yrs from APHV)	N
Boys			
8	6	-5	4
9	9	-4	8
10	20	-3	20
11	21	-2	28
12	22	-1	17
13	10	0	11
14	11	1	13
15	24	2	19
16	20	3	27
17	23	4	30
-	-	5	3
-	-	6	1
TOTAL BOYS	166		166
Girls			
8	3	-5	-
9	3	-4	4
10	8	-3	5
11	16	-2	10
12	19	-1	17
13	24	0	25
14	31	1	33
15	27	2	29
16	12	3	16
17	30	4	13
-	-	5	17
-	-	6	4
TOTAL GIRLS	173		173
TOTAL	339		

TABLE 3. Prediction of waist circumference from anthropometric, demographic and lifestyle-related variables in boys and girls.

BOYS

Best fit model: Model R-Square = 0.89, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Body mass (kg)	0.8 (0.04)	0.7, 0.9
Height (cm)	-0.2 (0.07)	-0.3, -0.08
Chronological Age (yrs)	-1.0 (0.37)	-1.7, -0.2

Variables entered but not retained in the final model: biological age, estimated total energy intake, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption, TV viewing category.

GIRLS

Best fit model: Model R-Square = 0.92, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Body mass (kg)	0.91 (0.03)	0.8, 1.0
Height (cm)	-0.37 (0.09)	-0.2, 0.2
Biological Age (yrs from APHV)	-1.03 (0.36)	-1.7, -0.3
Physical activity level (KKD)	-0.1 (0.07)	-0.3, -0.001

Variables entered but not retained in the final model: chronological age, estimated total energy intake, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption, TV viewing category.

TABLE 4. Prediction of total body fatness from anthropometric, demographic and lifestyle-related variables in boys and girls.

BOYS

Best fit model: Model R-Square = 0.62, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Chronological Age (yrs)	-2.3 (0.42)	-3.1, -1.5
Body mass (kg)	0.4(0.04)	0.3, 0.5
Height (cm)	-0.3 (0.08)	-0.4, -0.1

Variables entered but not retained in the final model: biological age, physical activity level, estimated total energy intake, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption, TV viewing category.

GIRLS

Best fit model: Model R-Square = 0.76, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Body mass (kg)	0.56 (0.03)	0.5, 0.6
Height (cm)	-0.64 (0.06)	-0.5, 0.5
Total kcals	-0.00 (0.000)	0.002, 0.000

Variables entered but not retained in the final model: chronological age, biological age, physical activity level, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption, TV viewing category.

TABLE 5. Prediction of trunk fatness from anthropometric, demographic and lifestyle-related variables in boys and girls.

BOYS

Best fit model: Model R-Square = 0.64, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Chronological Age (yrs)	-2.2 (0.45)	-3.1, -1.4
Body mass (kg)	-0.5 (0.05)	0.4, 0.6
Height (cm)	-0.3 (0.09)	-0.4, -0.1
Physical activity level (KKD)	-0.2 (0.09)	-0.4, -0.03

Variables entered but not retained in the final model: biological age, estimated total energy intake, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption, TV viewing category.

GIRLS

Best fit model: Model R-Square = 0.78, p<0.000

Independent variables	Beta estimate (standard error)	95% CI
Body mass (kg)	0.70 (0.04)	0.6, 0.8
Height (cm)	-0.76 (0.08)	-0.9, -0.6
Total kcals	-0.002 (0.001)	-0.003, -0.001
TV dichotomous	-2.4 (0.9)	-4.1, -0.6

Variables entered but not retained in the final model: biological age, physical activity level, servings other foods, fruit and vegetable servings, sugar-sweetened beverage consumption.

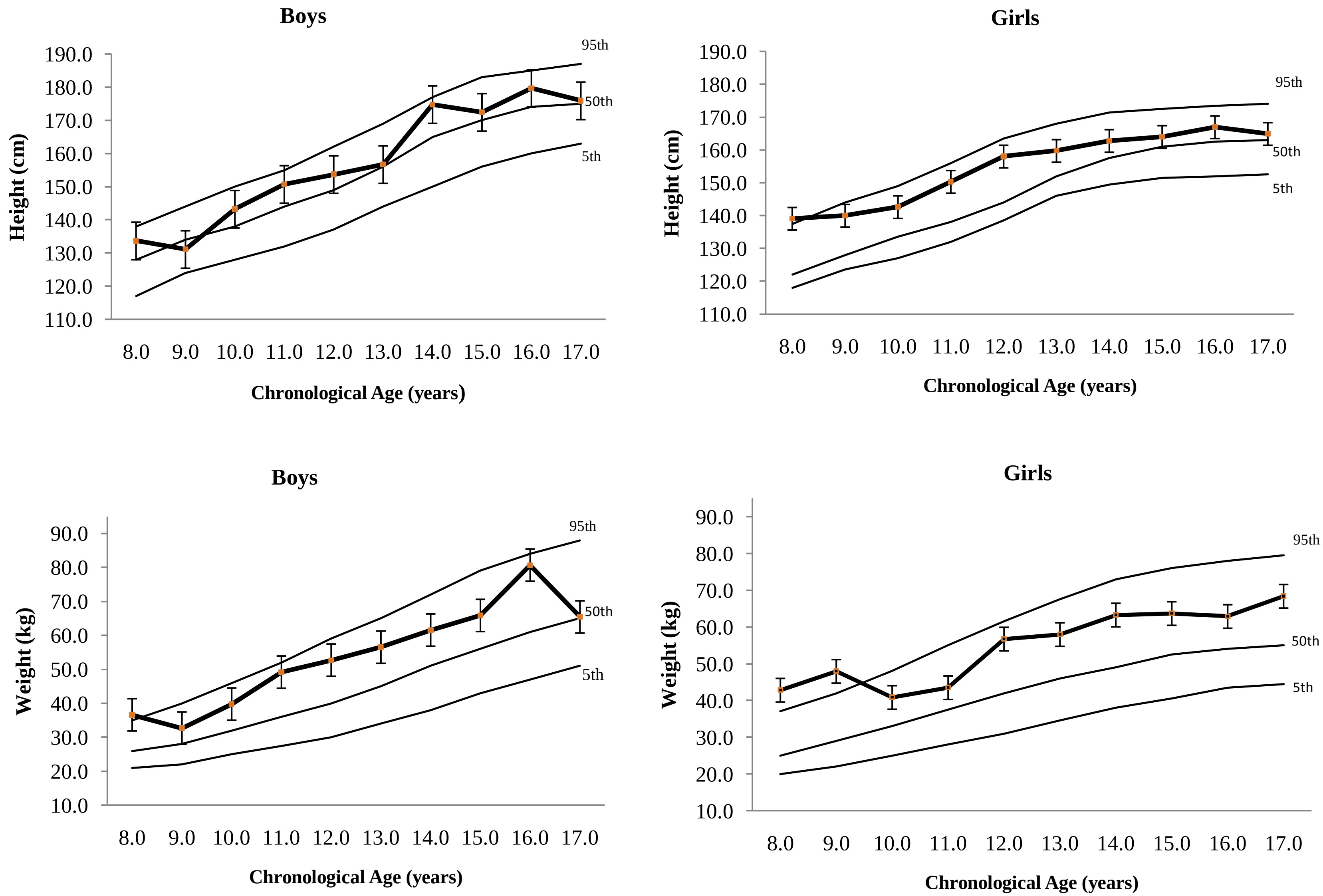

FIGURE 1. Heights and weights of boys and girls plotted against CDC reference standards (5^{th}, 50^{th} and 95^{th}).

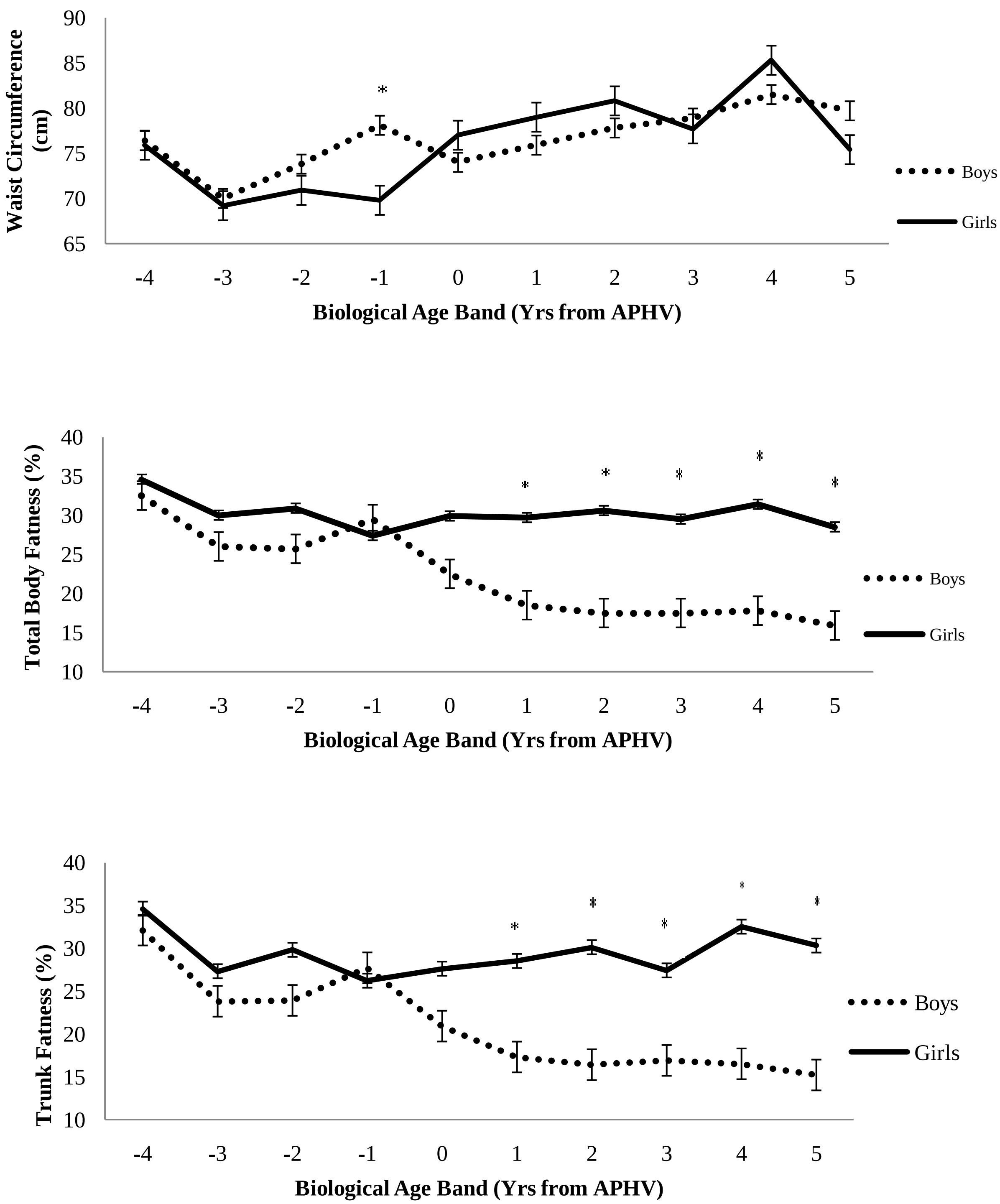

FIGURE 2. Measures of Adiposity - Waist Circumference, Total Body Fatness and Trunk Fatness of boys and girls by biological age band. Sex differences analyzed by Independent t-tests; where * indicates significance at the 0.05 level.

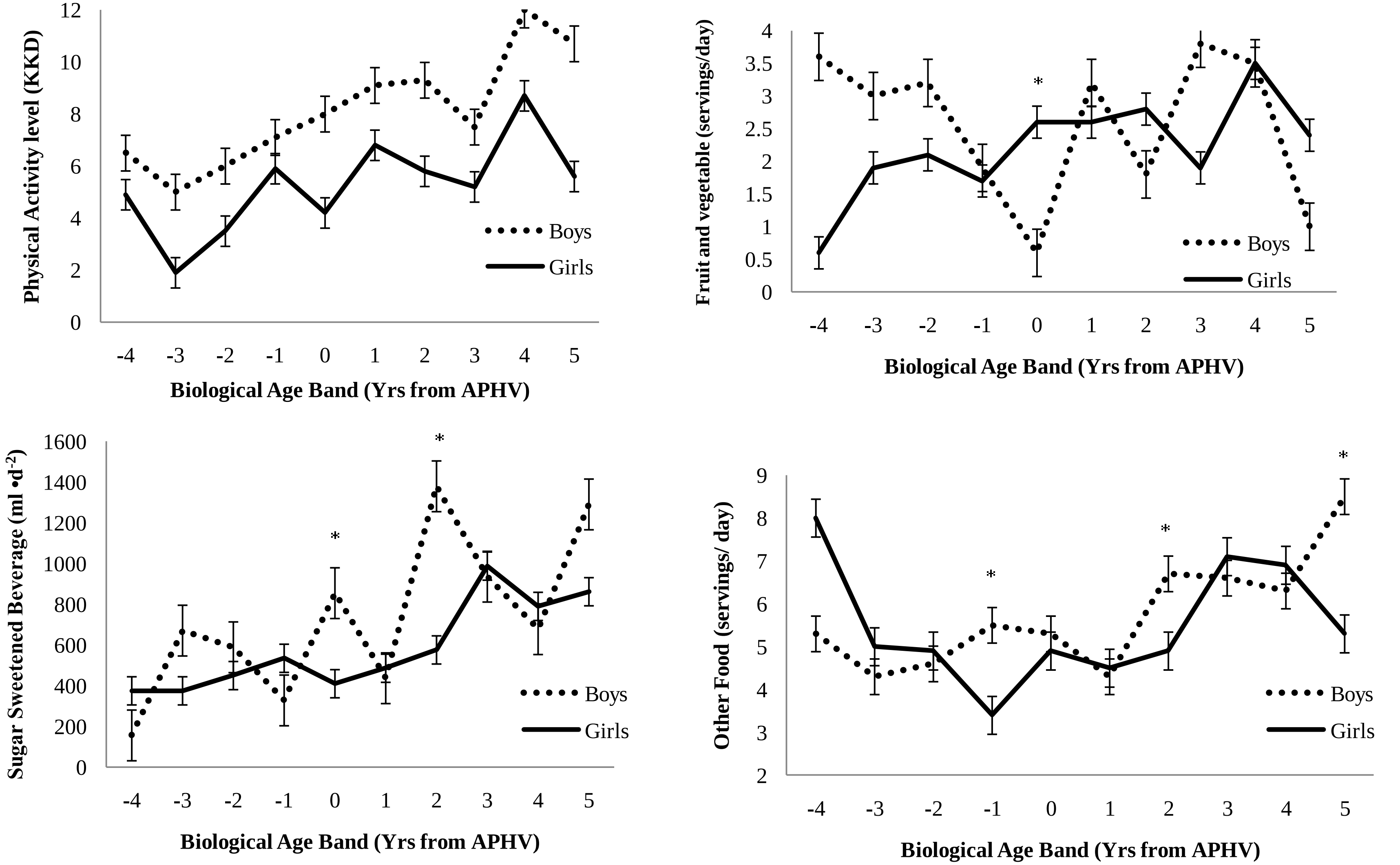

FIGURE 3. Physical activity and diet variables (mean ±SE) by biological age band. Sex differences analyzed by Independent t-tests; where * indicates significance at the 0.05 level.

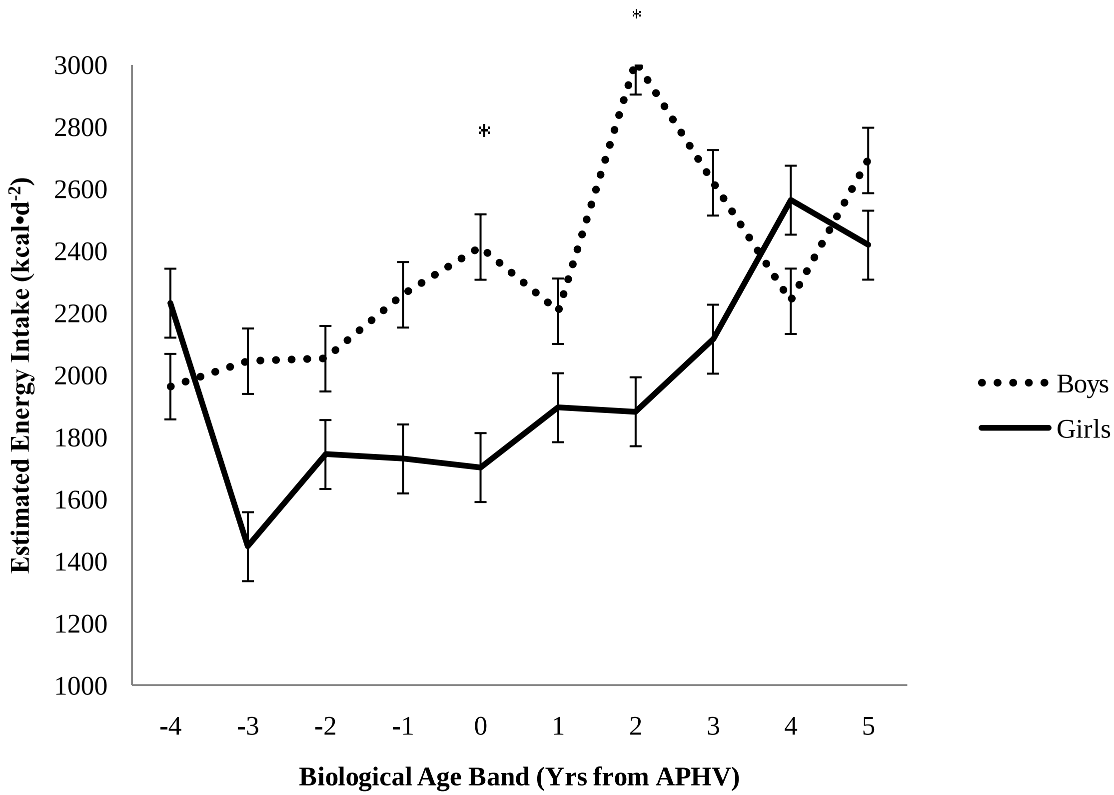

FIGURE 3. Physical activity and diet variables (mean ±SE) by biological age band. Sex differences analyzed by Independent t-tests; where * indicates significance at the 0.05 level.

7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The objective of this research was to study relationship(s) of ethnicity, physical activity and diet with adiposity development in Aboriginal youth. To meet this objective, three separate, yet inter-related studies were undertaken to: 1) comprehensively assess adiposity in Aboriginal youth and their age, sex and maturity matched Caucasian peers; 2) assess the role of ethnicity and sex on physical activity (PA) levels and identify the proportion of Aboriginal youth meeting PA and T.V. viewing recommendations; and 3) explore relationships of ethnicity, physical activity and diet with adiposity.

In study one, it was hypothesized that Aboriginal youth would have greater adiposity than their Caucasian peers. While much of the research to date has focused on BMI, this investigation used DXA and waist circumference to show that Aboriginal youth had greater total and central adiposity than their Caucasian counterparts.

Study two examined physical activity behaviors in relation to ethnicity and sex. It was hypothesized that the physical activity levels of Aboriginal youth would be lower than their Caucasian peers; that the majority of Aboriginal youth would not meet PA and T.V. viewing recommendations; and that Aboriginal boys would have higher adjusted physical activity energy expenditures than Aboriginal girls. Findings indicated that physical activity levels of the two ethnic groups were generally comparable, that Aboriginal boys had greater activity energy expenditures than girls, and that a greater percentage of boys were meeting the international recommendations for physical activity and T.V. viewing.

Study three built upon the first two investigations, to explore relationships of physical activity and diet with adiposity in Aboriginal youth. It was hypothesized that when age, size and maturity, and their interactions were accounted for, diet and physical activity variables would be related to adiposity (waist circumference, total body and trunk fatness). Results indicated physical activity was inversely related to adiposity level, independent of biological factors. Although energy intake was the sole dietary variable related to the adiposity measures, descriptives showed the eating behaviors (i.e., consumption of fruits and vegetables, sugar sweetened beverages and other foods) of the Aboriginal youth were sub-optimal when compared to current recommendations.

This research project is unique because it comprehensively assessed adiposity, diet and physical activity, and the relationships between these variables, in a relatively large sample of Aboriginal boys and girls. Furthermore, these relationships were established using a variety of measures (i.e., DXA, waist circumference, height and weight) while controlling for biological confounders. Overall, the results highlight the urgent need to promote physical activity and healthy eating in Aboriginal youth and set the stage for future research.

7.2 FUTURE RESEARCH

There are several limitations of this thesis project which should be addressed in future investigations. The cross-sectional nature does not allow one to establish causal relationships, highlighting the need for longitudinal research. Findings from this study showing physical activity levels are less than optimal may have been underestimated given the subjectivity of self report; therefore, future research should consider objective measures, such as accelerometry, to obtain a more accurate estimate of energy expenditure and explore varying intensities and types of physical activities on adiposity. It would also be beneficial to focus on one tribal group (e.g., Cree) rather than an admixture and to obtain socioeconomic information from all participants. Given that genetic factors, economic variables, social support systems and cultural norms may influence physical activity, healthy eating and adiposity levels, future studies describing adiposity and lifestyle behaviors in the context of biological, social, cultural and environmental factors are warranted.

I recommend a few strategies that may improve future research in this area. While the use of technical equipment such as DXA was a beneficial feature for this study, an alternative measure or a portable DXA would minimize travel requirements and improve subject retention. To encourage subject participation, I would provide more incentives to the Aboriginal youth and more resources to support the Aboriginal teachers and parents involved. I would also hire an Aboriginal research coordinator to enhance relations and rapport with each school.

7.3 PERSONAL REFLECTION

As a non-Aboriginal researcher, I have learned many important lessons from this thesis project. As highlighted in the methods, this research began with a successful collaboration between the University and an urban Aboriginal High School, which extended to include numerous schools and communities. I have learned of the need for collaborative research involving respectful relationships and participatory research designs, whereby the communities themselves drive the research so that it is relevant and meaningful. It is my hope that the work I have done will instigate future work contributing to the development of effective and sustainable programs targeting healthy eating and physical activity in Aboriginal youth and that the partnerships I helped establish will continue.

I have also learned about the Aboriginal culture from this research, and in turn have learned more about myself and my culture. I have learned through the Medicine Wheel that well being in life stems from the balance of four interconnected, yet distinct dimensions (the physical, emotional, mental and spiritual). I believe that physical activity has enormous potential for contributing to physical, emotional, mental and spiritual wellbeing and may be the preventative medicine needed to help alleviate many of the social ills currently facing Aboriginal people. The school and community are two key places in which physical activity and healthy eating can be promoted, and existing models (i.e., Kahnawake Schools Diabetes Prevention Project and the Sandy Lake First Nation School Diabetes Prevention Program) could be adapted to target other Canadian Aboriginal communities.

REFERENCE LIST

Aaron, D.J., Kriska, A.M., Dearwater S.R., Cauley, J.A., Metz, K.F. & LaPorte, R.E. (1995). Reproducibility and validity of an epidemiological questionnaire to assess past year physical activity in adolescents. *American Journal of Epidemiology*, 142, 191 201.

Abelson, P. & Kennedy, D. (2004). The obesity epidemic. *Science*, 304, 1413.

Adult Treatment Panel III (2002). Third report of the National Cholesterol Education Program (NCEP) Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). Final Report. *Circulation*, 106, 3143-3142.

Active Healthy Kids Canada (2009). Report Card on Physical Activity for Children and Youth, 2009: Active kids are fit to learn. URL: http://www.activehealthykids.ca/ecms.ashx/ReportCard2009/ParticipactionReportCard_FINALEN.pdf. Accessed September 21, 2009.

American Academy of Pediatrics (2007). Committee on Public Education; Policy Statement: Children, adolescents and television. *Pediatrics*, 107, 423-426.

Anand, S.S., Yusuf, S., Jacobs, R., Davis, A.D., Yi, Q., Gerstein, H. et al. (2001). Risk factors, atherosclerosis, and cardiovascular disease among Aboriginal people in Canada: The Study of Health Assessment and Risk Evaluation in Aboriginal peoples (SHARE-AP). *Lancet*, 358, 1147-53.

Anand, S.S., Davis, A.D., Ahmed, R., Jacobs, R., Xie, C. Hill, et al. (2007). A family – based intervention to promote healthy lifestyle in an Aboriginal community in Canada. *Canadian Journal of Public Health*, 98, 447 – 452.

Anderson, K. & Chad, K. (2006). Joe Duquette health promotion school report. Saskatoon Catholic Board of Education: University of Saskatchewan.

Anderson, K.A., Baxter Jones, A.D.G., Faulkner, R.A., Muhajarine, N., Henry, C.J. & Chad, K.E. (2010).Total and central adiposity in Aboriginal youth and their Caucasian peers. *International Journal of Pediatric Obesity*, in press.

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S., et al. (2006). Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *The Lancet*, 368, 299-304.

Bailey, D.A. (1997). The Saskatchewan Pediatric Bone Mineral Accrual Study: bone mineral acquisition during the growing years. *International Journal of Sports Medicine*, 18, S191-194.

Bailey, D.A., Faulkner, R.A. & McKay, H.A. (1996). Growth, physical activity, and bone mineral acquisition. *Exercise and Sport Science Reviews,* 24, 233-266.

Bailey, D.A., McKay, H.A., Mirwald, R.L., Crocker, P.R. & Faulkner, R.A. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: the University of Saskatchewan bone mineral accrual study. *Journal of Bone and Mineral Research*, 14, 1672-1679.

Baker, J. L., Olsen, L. W. & Sorensen, T. I. (2007). Childhood body-mass index and the risk of coronary heart disease in adulthood. *The New England Journal of Medicine*, 357, 2329-2337.

Ball, G. D. & McCargar, L. J. (2003). Childhood obesity in Canada: a review of prevalence estimates and risk factors for cardiovascular diseases and type 2 diabetes. *Canadian Journal of Applied Physiology, 28*, 117-140.

Ball, G.D. & Willows, N.D. (2005). Definitions of pediatric obesity. *CMAJ, 172*, 309-310.

Ballew, C., White, L., Strauss, K. F., Benson, L. J., Mendlein, J. M. & Mokdad, A. H. (1997). Intake of nutrients and food sources of nutrients among the Navajo: findings from the Navajo Health and Nutrition Survey. *Journal of Nutrition,* 127, 2085S - 2093S.

Beamer, B. (2003). Genetic Influence on Obesity. In: Anderson, R. (Ed). *Obesity: Etiology, Assessment, Treatment and Prevention.* Champaign: Human Kinetics. pp. 43 –56.

Berenson, G.S., Srinivasan, S.R., Bao, W., et al. (1998). Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults: The Bogalusa Heart Study. *New England Journal of Medicine*, 338, 1650-1656.

Bernard, L., Lavallee, C., Gray-Donald, K. & Delisle, H. (1995). Overweight in Cree schoolchildren and adolescents associated with diet, low physical activity, and high television viewing. *Journal of American Dietetic Association*, 95, 800-802.

Birmingham, C.L., Muller, J.L., Palepu, A., Spinelli, J.J. & Anis, A.H. (1999). The cost of obesity in Canada. *Canadian Medical Association Journal*, 160, 483-488.

Black, A.E., Coward, W.A., Cole, T.J. & Prentice, A.M. (2004). Human energy expenditure in affluent societies: an analysis of 574 doubly-labeled water measurements. *European Journal of Clinical Nutrition*, 50, 72-92.

Bobet, E. (1998). *Diabetes among First Nations People: Information from the 1991 Aboriginal Peoples Survey*. Ottawa: Minister of Public Works and Government Services.

Brambilla, P., Bedogni, G., Moreno, L.A., Goran, M.I., Gutin, B., Fox, K.R., et al. (2006). Cross validation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. *International Journal of Obesity*, 30, 23-30.

Broussard, B. A., Sugarman, J. R., Bachman-Carter, K., Booth, K., Stephenson, L., Strauss, K. F., et al. (1995). Toward a comprehensive obesity prevention program in Native American communities. *Obesity Research,* 3, 289S-297S.

Bryan, S.N., Tremblay, M.S., Perez, C.E., Ardern, C.I. & Katzmarzyk, P.T. (2006). Physical activity and ethnicity: evidence from the Canadian Community Health Survey. *Canadian Journal of Public Health,* 97, 271-276.

Bunt, J.C., Salbe, A.D., Harper, I.T., Hanson, R.L. & Tataranni, P.A. (2003). Weight, adiposity, and physical activity as determinants of an insulin sensitivity index in Pima Indian children. *Diabetes Care*, 26, 2524-2530.

Burger, J. (1987). Report from the Frontier. *The State of the World's Indigenous Peoples.* London: Zed Books Ltd.

Butte, N. (2001). The role of breastfeeding in obesity. *Pediatric Clinics of North America*, 48, 189-198.

Calle, E.E., Thun, M.J., Petrelli, J.M., et al. (1999). Body mass index and mortality in a prospective cohort of U.S. adults. *New England Journal of Medicine*, 23, 1097-1105.

Campbell, A. (2002). Type 2 diabetes and children in Aboriginal communities: the array of factors that shape health and access to health care. *Health Law Journal*, 10, 147-1068.

Canadian Paediatric Society, First Nations and Inuit Health (2005). Risk reduction for type 2 diabetes in Aboriginal children in Canada. *Paedatric Childrens Health*, 10, 49-52.

Canadian Society for Exercise Physiology (CSEP) (2003). *The Canadian Physical Activity, Fitness and Lifestyle Appraisal Resource Manual (3rd edition).*Canadian Society for Exercise Physiology: Ottawa, Canada.

Caspersen, C.J., Powell, K.E. & Christenson, G.M. (1985). Physical activity, exercise and physical fitness: definitions and distinctions for health-related research. *Public Health Reports*, 100, 126-130.

Centers for Disease Control and Prevention (2009). Third National Health and Nutrition Examination Survey (NHANES III) waist circumference reference. URL: http://www.cdc.gov/growthcharts/ (accessed 9 September 2009).

Chan, G. (1991). Performance of dual-energy x-ray absorptiometry in evaluating bone, lean body mass, and fat in pediatric subjects. *Journal of Bone and Mineral Research,* 7, 369 – 374.

Chen, L.C. & Berlinguer, G. (2001). Health equity in a globalizing world. *Challenging Inequities in Health: From Ethics to Action*. New York: Oxford University Press.

Coble, J.D. & Rhodes, R.E. (2006). Physical activity and Native Americans. *American Journal of Preventive Medicine,* 31, 36-46.

Connelly, P.W., Hanley, A.J., Harris, S.B., Hegele, R.A. & Zinman, B. (2003). Relation of waist circumference and glycemic status to C-reactive protein in the Sandy Lake Oji-Cree. *International Journal of Obesity and Related Metabolic Disorders,* 27, 347 54.

Cole, T. J., Bellizzi, M. C., Flegal, K. M. & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal,* 320, 1240 - 1243.

Cook**,** S., Weitzman, M., Auinger, P., Nguyen, M. & Dietz, W.H. (2003). Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988-1994. *Archives of Pediatrics and adolescent Medicine,* 157, 821-27

Corbin, W.R., Corbin, C.B., Pangrazi, R.P., Petersen, G. & Pangrazi, D. (1997). Self esteem profiles: a comparison of children above and below national criteria for body fatness. *The Physical Educator,* 54, 57 – 56.

Craig, C.L., Russell, S.J., Cameron, C. & Beaulieu, A. (1999). Foundation for joint action: reducing physical inactivity. Ottawa: Canadian Fitness and Lifestyle Research Institute.

Crocker, P.R.E, Bailey, D.A., Faulkner, R.A., Kowalski, K.C., & McGrath, R. (1997). Measuring general levels of physical activity: Preliminary evidence for the physical activity questionnaire for older children. *Medicine and Science in Sports and Exercise*, 29, 1344 – 1349.

Daniels, S. R. (2006). The consequences of childhood overweight and obesity. *The Future of Children, Future Child,* 16, 47-68.

Daniels, S. R., Morrison, J.A., Sprecher, D.L., et al. (1999). Association of body fat distribution and cardiovascular risk factors in children and adolescents. *Circulation,* 99, 541 – 50.

Daniels, S. R., Khoury, P. R., & Morrison, J. A. (2000). Utility of different measures of body fat distribution in children and adolescents. *American Journal of Epidemiology,* 152, 1179-1184.

Dean, H. (1998). NIDDM-Y in First Nation children in Canada. *Clinical Pediatrics,* 37, 89-96.

Dean, H.J., Young, T.K., Flett, B. & Wood-Steiman, P. (1998). Screening for type-2 diabetes in Aboriginal children in northern Canada. *Lancet,* 352, 1523-1524.

Dean, H.J. & Sellers, E.A. (2003). The changing face of type 2 diabetes of youth in Manitoba. 1986-2002. *Canadian Journal of Diabetes*, 27, 449-454.

Dean, H.J. & Sellers, E.A. (2002). Type 2 diabetes, polycystic ovary syndrome and the insulin resistance syndrome in adolescents: Are they one big iceberg? *Paediatric Childrens Health*, 7, 333 – 336.

Dencker, M., Thorsson, O., Karlsson, M. K., Linden, C., Wollmer, P., & Andersen, L.B.(2008). Daily physical activity related to aerobic fitness and body fat in an urban sample of children. *Journal of Medicine and Science in Sports,* 18, 728-735.

Dept of Health and Ageing (2006). *Factbook.* Sydney, Australia. URL:www.health.gov.au/internet/wcms/publishing.nsf/Content/Factbook2006-1.

Despres, J.P. & Lemieux, I. (2006). Abdominal obesity and metabolic syndrome. *Nature,* 14, 881 – 887.

Dietz, W. H. (1998). Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics*, 101, 518-525.

Downs, S. M., Marshall, D., Ng, C., & Willows, N. D. (2008). Central adiposity and associated lifestyle factors in Cree children. *Applied Physiology, Nutrition and Metabolism,* 33, 476-482.

Dyck, R, Klomp, H., Tan, L.K., Turnell, R.W. & Boctor, M.A. (2002). A comparison of rates, risk factors, and outcomes of gestational diabetes between aboriginal and non aboriginal women in the Saskatoon health district. *Diabetes Care*, 25, 487-93.

Dyck, R.F., Klomp, H. & Tan, L. (2001). From "thrifty genotype" to "hefty fetal phenotype": the relationship between high birth weight and diabetes in Saskatchewan Registered Indians. *Canadian Journal of Public Health*, 92, 340-344.

Dyck, R.F. (2005). Tracking ancient pathways to a modern epidemic: diabetic end-stage renal disease in Saskatchewan Aboriginal people. *Kidney International*, 97, 553–7.

Dzioba, D. H. (1998). *Body Composition, energy expenditure, and dietary intakes in a sample of children with fetal alcohol syndrome*. Saskatoon: University of Saskatchewan.

Eisenmann, J. C., Arnall, D. A., Kanuho, V., & McArel, H. (2003). Growth status and obesity of Hopi children. *American Journal of Human Biology,* 15, 741 - 745.

Eisenmann, J.C., Bartee, R.T., & Wang, M.Q. (2002). Physical activity, TV viewing and weight in U.S. Youth: 1999 Youth Risk Behaviour Survey. *Obesity Research*, 10, 379 – 385.

Ellis, K.J., Shypailo, R.J., Pratt, J.A., & Pond, W.G. (1994). Accuracy of dual-energy xray absorptiometry for body-composition measurements in children. *American Journal of Clinical Nutrition,* 60, 660-665.

ESHA Research (2001). The Food Processor SQL. Version 8.5, Salem, OR.

Fagot-Campagna, A. (2000). Emergence of type 2 diabetes mellitus in children: epidemiologic evidence. *Journal of Pediatric Endocrinology and Metabolism,* 13(Suppl 6), 1395- 1402.

Farooqi, I.S. & O'Rahilly, S. (2007). Genetic factors in human obesity. *Obesity Reviews,* 8, 37-40.

First Nations Centre (2005). *First Nations Regional Longitudinal Health Survey (RHS) 2002/03: results for adults, youth and children living in First Nations communities*. Ottawa: National Aboriginal Health Organization.

Fleming, T., Kowalski, K.C., Humbert, M.L., Fagan, K.R. Cannon, M.J., Girolami, T.M. (2006). Body-related emotional experiences of young Aboriginal women. *Qualitative Health Research,* 16, 517-537.

Fontvielle, A. M., Kriska, A. & Ravussin, E. (1993). Decreased physical activity in Pima Indians compared with Caucasians. *International Journal of Obesity & Related Metabolic Disorders*, 17, 445-452.

Freedman, D. S., Dietz, W. H., Srinivasan, S. R. & Berenson, G. S. (1999). The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics,* 103, 1175-1182.

Freedman, D. S., Serdula, M. K., Percy, C. A., Ballew, C. & White, L. (1997). Obesity, levels of lipids and glucose, and smoking among Navajo adolescents. *Journal of Nutrition*, 127, 2120S-2127S.

Freedman D. S., Khan, L.K., Serdula, M.K., Dietz, W.H., Srinivasan, S.R. & Berenson, G.S. (2003). The relation of menarche age to obesity in childhood and adulthood: the Bogalusa Heart Study. *BMC Pediatrics*, 3, 3-11.

Garnett, S.P., Cowell, C.T., Baur, L.A., Shrewsbury, V.A., Chan, A., Crawford, D., et al. (2005). Increasing central adiposity: the Nepean longitudinal study of young people aged 7 - 8 to 12-13y. *International Journal of Obesity*, 29, 1353 - 1360.

Garriguet, D. (2008). Obesity and the eating habits of the Aboriginal population. *Health Reports,* 19, 1 – 15.

Gilbert, T.J., Percy, C.A., Sugarman, J.R., Benson, L., & Percy, C. (1992). Obesity among Navajo adolescents: relationship to dietary intake and blood pressure. *American Journal of Diseases in Children*, 146, 289-95.

Gillis, L.J. & Bar-Or, O. (2003). Food away from home, sugar-sweetened drink consumption and juvenile obesity. *Journal of the American College of Nutrition*, 22, 539 – 545.

Gittelsohn, J., Harris, S.B., Thorne-Lyman, A.L., Hanley, A.J., Barnie, A., & Zinman, B. (1996). Body image concepts differ by age and sex in an Ojibway-Cree community in Canada. *Journal of Nutrition*, 126, 2990-3000.

Gittelsohn, J., Wolever, T. M., Harris, S. B., Harris-Giraldo, R., Hanley, A. J. G., & Zinman, B. (1998). Specific patterns of food consumption and preparation are associated with diabetes and obesity in a Native Canadian community. *Journal of Nutrition*, 128, 541-547.

Goran, M.I. (1998). Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics*, 101, 505 - 518.

Goran, M.I., Driscoll, P., Johnson, R., Nagy, T.R., & Hunter, G. (1996). Cross-calibrationof body-composition techniques against dual-energy X-ray absorptiometry in young children. *American Journal of Clinical Nutrition,* 63, 299 - 305.

Goran, M.I., Nagy, T.R., Treuth, M.S., Trowbridge, C., Dezenberg, C., McGloin, A., et al. (1997). Visceral fat in white and African American prepubertal children. *American Journal of Clinical Nutrition*, 65, 1703 – 1708.

Goran, M. I., Reynolds, K. D. & Lindquist, C. H. (1999). Role of physical activity in the prevention of obesity in children. *International Journal of Obesity,* 23, S18 - S33.

Green, C., Blanchard, J.F., Young, T.K. & Griffith, J. (2003). The epidemiology of diabetes in the Manitoba -registered FN population: current patterns and comparative trends. *Diabetes Care,* 26, 1993-1998.

Grundy, S.M., Cleeman, J.I., Daniels, S.R., Donato, K.A., Eckel, R.H., Franklin, B.A., et al. (2005). American Heart Association. National Heart, Lung, and Blood Institute. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation,* 112, 2735-52.

Guo, S.S., Wu, W., Chumlea, W.C. & Roche, A.F. (2002). Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. *American Journal of Clinical Nutrition,* 76, 653 - 658.

Guo, S. S., Huang, L. M., Demerah, E., Towne, B., Chumlea, W. C. & Siervogel, R. M. (2000). Body mass index during childhood, adolescence and young adulthood in relation to adult overweight and adiposity: the Fels Longitudinal Study. *International Journal of Obesity,* 24, 1628 - 1635.

Gutin, B., Litaker, M., Islam, S., Manos, T., Smith, C. & Treiber, F. (1996). Body composition measurement in 9-11-y-old children by dual-energy X-ray absoprtiometry, skinfold-thickness measurements, and bioimpedance analysis. *American Journal of Clinical Nutrition*, 63, 287 – 292.

Hancox, R., Milne, B. & Poulton, R. (2004). Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *The Lancet*, 364, 257-262.

Hanley, A. J. G., Harris, S. B., Gittelsohn, J., Wolever, T. M. S., Saksvig, B. & Zinman, B. (2000). Overweight among children and adolescents in a Native Canadian community: prevalence and associated factors. *American Journal of Clinical Nutrition,* 71, 693 - 700.

Harris, S., Perkins, B. & Whalen-Brough, E. (1996). Non-insulin-dependent diabetes mellitus among First Nations children. *Canadian Family Physician*, 42, 869-76.

Health Canada (2005). Canadian Nutrient File, 2005 Version. URL: www.hc sc.gc.ca/fnan/nutrition/fiche-nutri-data/licence-eng.php.

Health Canada (2003). A statistical profile on the Health of First Nations in Canada. Ottawa, 2003.

Health Canada (2001). Diabetes among Aboriginal (First Nations, Inuit and Métis) people in Canada: the evidence. Available from: http://www.hcsc.gc.ca/fniah spnia/alt_formats/fnihb dgspni/pdf/pubs/diabete/2001_evidence_faitseng.pdf.

Health Canada (2003). *Canadian Guidelines for Body Weight Classification in Adults.* http://www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/nutrition/weight_book livres_des_poids-eng.pdf.

Health Canada (2007). Canada's Food Guide to Healthy Eating. URL: http://www.hc sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/food-guide aliment/print_eatwell_bienmang-eng.pdf.

Health Canada (2007). *Eating Well with Canada's Food Guide: First Nations, Inuit and Métis*. URL: http://www.hc-sc.gc.ca/fn-an/alt_formats/fnihb-dgspni/pdf/pubs/fnim pnim/2007_fnim-pnim_food-guide-aliment-eng.pdf.

Hegele, R. (2001). Genes and environment in type 2 diabetes and atherosclerosis in Aboriginal Canadians. *Current Atherosclerosis Reports,* 3, 216-221.

Hill, J.O. & Sarris, W.H.M. (1998). Energy expenditure in physical activity. In Bray, C.A., Bouchard, C. & James, W.P.T. (Eds). *Handbook of Obesity*, Marcel Dekker: Inc.

Ho, L., Gittelsohn, J., Sharma, S., Cao, X., Treuth, M., Rimal, R., et al. (2008). Food related behavior, physical activity, and dietary intake in First Nations – a population at high risk for diabetes. *Ethnicity & Health*, 13, 335-349.

Hologic Inc. (2002). A summary of scientific presentations at the 9th Bone Densitometry Workshop and the American Society of Bone Mineral Research. New advances in bone densitometry: QDR-2000 performance validation. Hologic, Inc.

House of Commons Canada (2007). *Healthy Weights for Healthy Kids*: *Report of the Standing Committee on Health.* Ottawa: Communication Canada – Publishing.

Horn, O. K., Jacobs-Whyte, H., Ing, A., Bruegel, A., Paradis, G., & Macaulay, A. C. (2007). Incidence and prevalence of type 2 diabetes in the First Nation community of Kahnawa:ke, Quebec, Canada, 1986 - 2003. *Canadian Journal of Public Health,* 98, 438-443.

Horn, O. K., Paradis, G., Potvin, L., Macaulay, A. C., & Desrosiers, S. (2001). Correlates and predictors of adiposity among Mohawk children. *Preventive Medicine,* 33, 274 - 281.

Indian and Northern Affairs Canada (2002). *Words first: An evolving terminology relating to Aboriginal peoples in Canada.* Ottawa: Government of Canada.

Iuliano-Burns, S., Whiting, S.J., Faulkner, R.A., & Bailey, D.A. (1999). Levels, sources, and seasonality of dietary calcium intake in children and adolescents enrolled in the University of Saskatchewan Pediatric Bone Mineral Accrual Study. *Nutrition Research*, 19, 1471-1483.

Janz, K.F., Dawson, J.D., & Mahoney, L.T. (2002). Increases in physical fitness during childhood improve cardiovascular health during adolescence: the Muscatine Study. *International Journal of Sports Medicine,* 23, S15 – S21.

Janssen, I., Srinivasan, S.R., Chen, W., Malina, R.M., Bouchard, C., & Berenson, G.S. (2005). Combined influence of body mass index and waist circumference on coronary artery disease risk factors among children and adolescents. *Pediatrics,* 115, 1623-1630.

Janssen, I., Katzmarzyk, P.T., Boyce, W.F., King, M.A. & Pickett, W. (2004). Overweight and obesity in Canadian Adolescents and their associations with dietary habits and physical activity patterns. *Journal of Adolescent Health,* 35, 360-367.

Jimenez, M.M., Receveur, O., Trifonopoulos, M., Kuhnlein, H.V., Paradis, G. & Macaulay, A. C. (2003). Comparison of the dietary intakes of two different groups children (grades 4 to 6) before and after the Kahnawake Schools Diabetes Prevention Project. *Journal of the American Dietetic Association,* 103, 1191-1194.

Johnson, R., Driscoll, P. & Goran, M. (1996). Comparison of multiple-pass 24-hour recall estimates of energy intake with activity energy expenditure determined by the doubly labeled water method in young children. *Journal of American Dietetic Association*, 96, 1140-1144.

Karvetti, R.L. & Knuts, L.R. (1985). Validity of the 24-hour dietary recall. *Journal of the American Dietetic Association,* 85, 1437-1442.

Katzmarzyk, P. T. (2004). Waist circumference percentiles for Canadian youth 11 - 18y of age. *International Journal of Obesity,* 58, 1011 - 1015.

Katzmarzyk, P. T. (2008). Obesity and physical activity among Aboriginal Canadians. *Obesity*, 16, 184-190.

Katzmarzyk, P. T. & Ardern, C. I. (2004). Overweight and obesity mortality trends in Canada, 1985 - 2000. *Canadian Journal of Public Health,* 95, 16 - 20.

Katzmarzyk, P. T. & Malina, R. M. (1998). Obesity and relative subcutaneous fat distribution among Canadians of First Nation and European ancestry. *International Journal of Obesity and Related Metabolic Disorders,* 22, 1127 - 1131.

Katzmarzyk, P. T. & Janssen, I. (2004). The economic costs associated with physical inactivity and obesity in Canada: An Update. *Canadian Journal of Applied Physiology,* 29, 90 - 115.

Kiess, W. & Boettner, A. (2002). Obesity in the adolescent. *Adolescent Medicine: State of the art reviews*, 13, 181-190.

Kim, Y. & Lee, S. (2009). Physical activity and abdominal obesity in youth. Applied Physiology, *Nutrition and Metabolism,* 34, 571 – 581.

Kimm, S.Y., Barton, B.A., Obarzanek, E., McMahon, R.P., Kronsberg, S.S., Waclawiw, M.A et al. (2002). Obesity development during adolescence in a biracial cohort: the NHLBI Growth and Health Study. *Pediatrics,* 110, e54.

Klein, S., Burke, L.E., Bray, G.A., Blair, S., Allison, D.B., Pi-Sunyer, X., et al. (2004). Clinical implications of obesity with specific focus on cardiovascular disease: a statement for professionals from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism. *Circulation*, 110, 2952-2967.

Klein-Platat, C., Oujaa, M., Wagner, A., Haan, M. C., Arveiler, D., Schlienger, J. L., et al. (2005). Physical activity is inversely related to waist circumference in 12-y old French adolescents. *International Journal of Obesity,* 29, 9-14.

Kowalski, K.C., Crocker, P.R.E. & Faulkner, R.A. (1997). Validation of the physical activity questionnaire for older children. *Pediatric Exercise Science,* 9, 174 – 186.

Kriska, A.M. & Caspersen, C.J. (1997). Modifiable activity questionnaire. In A collection of physical activity questionnaires for health-related research. *Medicine and Science in Sports and Exercise,* 29, S5–S9 and S73–S78.

Kriska, A. (2000). Ethnic and cultural issues in assessing physical activity. *Research Quarterly for Exercise and Sport,* 71, 47-53.

Kriska, A.M., Saremi, A., Hanson, R.L., Bennett, P.H., Kobes, S., Williams, D.E. et al. (2003). Physical activity, obesity, and the incidence of type 2 diabetes in a high risk population. *American Journal of Epidemiology,* 158, 669-75.

Kriska, A. M., Knowler, W. C., LaPorte, R. E., Drash, A. L., Wing, R. R., Blair, S. N. et al. (1990). Development of a questionnaire to examine relationship of physical activity and diabetes in Pima Indians. *Diabetes Care*, 13, 401- 411.

Kuczmarski, R.J., Ogden, C.L., Grummer-Strawn, L.M. et al. (2000). CDC growth charts: United States. *Advance Data*, 314, 1-27.

Kuhnlein, H.V., Receveur, O., Soueida, R. & Egeland, G.M. (2004). Arctic indigenous peoples experiences the nutrition transition with changing dietary patterns and obesity. *Journal of Nutrition*, 134, 1447 – 1453.

Lau, D.C.W., Douketis, J.D., Morrison, K.M., Hramiak, I.M., Sharma, A.M. & Ur, E. (2007). Canadian clinical practice guidelines on the management and prevention of obesity in adult and children. *Canadian Medical Association Journal*, 176, S1-S13.

Lauer, R.M. & Clarke, W.R. (1995). Childhood risk factors for high adult blood pressure: The Muscatine Study. *Pediatrics*, 25, 1056-1062.

Lear, S. A. (2005). Waist circumference is simpler than body mass index. *Clinical Chemistry*, 51, 1082-1083.

Lear, S.A., Chen, M.M., Frohlich, J.J. & Birmingham, C.L. (2002). The relationship between waist circumference and metabolic risk factors: cohorts of European and Chinese descent. *Metabolism*, 51, 1427-1432.

Leslie, W.D., Weiler, H.A. & Nyomba, B.L.G. (2007). Ethnic differences in adiposity and body composition: the First Nations bone health study. *Applied Physiology Nutrition and Metabolism*, 32, 1065-1072.

Liu, J., Young, T.K., Zinman, B., Harris, S.B., Connelly, P.W., & Hanley, A.J. (2006). Lifestyle variables, non-traditional cardiovascular risk factors and the metabolic syndrome in an Aboriginal Canadian population. *Obesity*, 14, 500-508.

Livingstone, M.B.E., Robson, P.J. & Wallace, J.M.W. (2004). Issues in dietary intake assessment of children and adolescents. *British Journal of Nutrition*, 92, S213 – S222.

Lohman, T.G. (1996). Dual energy x-ray absorptiometry. In: Roche, A.F., Heymsfield, S.B. & Lohman, T.G. (Eds.). *Human Body Composition*. Champaign: Human Kinetics.

Ludwig, D.S., Peterson, K.E., & Gortmaker, S.L. (2001). Relation between consumption of sugar sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*, 357, 505-508.

MacMillan, H. L., MacMillan, A. B., Offord, D. R., & Dingle, J. L. (1996). Aboriginal health. *Canadian Medical Association Journal*, 155, 1569-1578.

Maes, H.H., Neale, M.C. & Eaves, L.J. (1997). Genetic and environmental factors in relative body weight and human adiposity. *Behavioral Genetics*, 27, 1997, 325 – 351.

Maffeis, C., Pietrobelli, A., Grezzani, A., Provera, S. & Tato, L. (2001a). Waist circumference and cardiovascular risk factors in pre-pubertal children. *Obesity Research*, 9, *1*79 – 187.

Maffeis, C., Corciulo, N., Livieri, C., Rabbone, I., Trifiro G., Falorni, A., et al. (2003). Waist circumference as a predictor of cardiovascular and metabolic risk factors in obese girls. *European Journal of Clinical Nutrition*, 57, 566–72.

Mahoney, L.T., Burns, T.L., Stanford, W., Thompson, B.H., Witt, J.D., Rost, C.A., et al. (1996). Coronary risk factors measured in childhood and young adult life are associated with coronary artery calcification in young adults: the Muscatine Study. *Journal of the American College of Cardiology*, 27, 277-284.

Malik, V.S., Schulze, M.B. & Hu, F.B. (2006). Intake of sugar-sweetened beverages and weight gain: a systematic review. *American Journal of Clinical Nutrition*, 84, 274-288.

Malina, R.M. & Bouchard, C. (2004). Timing and sequence of changes during adolescence. In: Malina RM, Bouchard C, Bar-Or O. (Eds.). *Growth, Maturation and Physical Activity*. Champaign: Human Kinetics.

Malina, R.M. (1996). Regional body composition: age, sex, and ethnic variation. In: Roche, A.F., Heymsfield, S.B. & Lohman, T.G. (Eds.). *Human Body Composition*. Champaign: Human Kinetics.

Malina, R. M. (2002). Exercise and Growth: Physical Activity as a Factor in Growth and Maturation. In Cameron, N. (Ed.). *Human Growth and Development*. USA: Academic Press.

Malina, R. M. & Katzmarzyk, P. T. (1999). Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents. *American Journal of Clinical Nutrition*, 70, 131S-136S

Marshall, W.A. & Tanner, J.M. (1970). Variations in the pattern of pubertal changes in girls. *Archives of Disease in Children*, 45, 291-303.

Marshall, S.J. & Welk, G.J. (2008). Definitions and Measurement. In Smith, A.L., Biddle, S.J.H. (Eds). *Youth physical activity and sedentary behavior: Challenges and solutions.* Champaign: Human Kinetics.

McCarthy, H.D., Ellis, S.M., & Cole, T.J. (2003). Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. *British Medical Journal*, 326, 624-627.

McGavock, J., Sellars, E., & Dean, H. (2007). Physical activity for the prevention and management of youth-onset type 2 diabetes mellitus: focus on cardiovascular complications. *Diabetes and Vascular Disease Research*, 4; 305-310.

McGill, H.C. Jr., McMahan, C.A., Zieske, A.W., Malcom, G.T., Tracy, R.E., & Strong, J.P. (2001). Effects of non-lipid risk factors on atherosclerosis in youth with a favorable lipoprotein profile. *Circulation,* 103, 1546-1550.

McQuaid Cox, J. (1990). Pediatric nutritional assessment. *Journal of Pediatrics and Perinatal Nutrition*, 2, 17-41.

Ministry of Social Development (2006). *The Social Report 2006.* Auckland, New Zealand. URL: www.socialreport.msd.govt.nz.

Mirwald, R.L., Baxter-Jones, A.D., Bailey, D.A., & Beunen, G.P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*, 34, 689-94.

Mitchell, M.S. (2008). Frequency and intensity of physical activity are associated with insulin resistance in First Nations children and adolescents in 2 remote villages in northern British Columbia, Canada [MSc.]. Victoria: University of Victoria.

Molnar, D. & Livingstone, B. (2000). Physical activity in relation to overweight and obesity in children and adolescents. *European Journal of Pediatrics*, 159, S45 – S55.

Morrison, J.A., Khoury, P.R., Chumlea, W.C., et al. (1994). Body composition measures from underwater weighing and dual energy x-ray absorptiometry in black and white girls: a comparative study. *American Journal of Human Biology,* 6, 481 – 90.

Mundt, C., Baxer-Jones, A.D.G., Whiting, S.J., Bailey, D.A., Faulkner, R.A. & Mirwald, R.L. (2006). Relationships of activity and sugar drink intake on fat mass development in youths. *Medicine and Science in Sports and Exercise*, 38, 1245 – 1254.

Must, A. & Strauss, R. S. (1999). Risks and consequences of childhood and adolescent obesity. *International Journal of Obesity,* 23, S2-S11.

Nassis, G.P. & Sidossis, L.S. (2006). Methods for assessing body composition, cardiovascular and metabolic function in children and adolescents: implications for exercise studies. *Current Opinions in Clinical Nutrition and Metabolic Care*, 9, 560-567.

Neel, JV. (1962). Diabetes Mellitus: A ‘Thrifty Genotype’ rendered detrimental by ‘Progress’? *American Journal of Human Genetics*, 14, 353 – 362.

Neumark-Sztainer, D., Story, M., Resnick, M. D. & Blum, R. W. (1997). Psychosocial concerns and weight control behaviors among overweight and nonoverweight Native American adolescents. *Journal of the American Dietetic Association*, 97, 598-604.

Ng, C., Marshall, D., & Willows, N. D. (2006). Obesity, adiposity, physical fitness and activity levels in Cree children. *International Journal of Circumpolar Health,* 65, 322 330.

Ngnie Teta, I. (2002). *Secular Trends in the Physical Growth of Cree Children*. Cree Board of Health and Social Services of James Bay.

Norton K., Whittingham, N., Carter, L., Kerr, D., Gore, C. & Marfell-Jones M. (1996). Measurement techniques in anthropometry. In: Norton, K., Olds, T., (Eds.). *Anthropometrica.* Sydney, NSW: University of NSW Press. p. 20-6.

Olshansky, S.J., Passaro, D.J., Hershow, R.C., Layden, J., Carnes, B.A., Brody, J. et al. (2005). A potential decline in life expectancy in the United States in the 21st century. *New England Journal of Medicine, 3*52, 1135 – 37.

Ortega, F.B., Ruiz, J. & Sjostrom, M. (2007). Physical activity, overweight and central adiposity in Swedish children and adolescents: the European Heart Study. *International Journal of Behavioral Nutrition and Physical Activity*, 4, doi:10.1186/1479-5868-4-61.

Parsons, T. J., Power, C. & Summerbell, C. D. (1999). Childhood predictors of adult obesity: a systematic review. *International Journal of Obesity*, 23, S1 - S107.

Patrick, K., Norman,G.J., Calfas, K.J., Sallis, J.F., Zabinski, M.F., Rupp, J., et al. (2004). Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Archives of Pediatric and Adolescent Medicine,* 158, 385-390.

Perez, C.E. (2002). Fruit and vegetable consumption. *Health Reports,* 13, 23 – 31.

Pietrobelli, A., Faith, M. S., Allison, D. B., Gallagher, D., Chiumello, G. & Heymsfield, S. B. (1998). Body mass index as a measure of adiposity among children and adolescents: A validation study. *Journal of Pediatrics,* 132, 204-210.

Pintauro, S. J., Nagy, T. R., Duthie, C. M. & Goran, M. I. (1996). Cross-calibration of fat and lean measurements by dual-energy x-ray absorptiometry to pig carcass analysis in the pediatric body weight range. *American Journal of Clinical Nutrition,* 63, 293-298.

Pioro, M.P., Dyck, R.F., & Gillis, D.C. (1996). Diabetes prevalence rates among First Nations adults on Saskatchewan reserves in 1990: Comparison by tribal grouping, geography and with non-First Nations people. *Canadian Journal of Public Health*, 87, 325 – 328.

Potvin, L., Desrosiers, S., Trifonopoulos, M., Leduc, M., Rivard, M., Macaulay, A.C., et al. (1999). Anthropometric characteristics of Mohawk children aged 6 to 11 years: A population perspective. *Journal of American Dietetic Association*, 99, 955 61.

Pouliot, M.C., Despres, J.P., Lemieux, S., Moorjani, S., Bouchard, C., Tremblay, A., et. al. (1994). Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *American Journal of Cardiology,* 73, 460-8.

Raine, K. (2004). *Overweight and Obesity in Canada: A Population Health Perspective*. Ottawa: Canadian Institute for Health Information.

Rankinen, T., Kim, S.Y., Perusse, L., Despres, J.P. & Bouchard, C. (1999). The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. *International Journal of Obesity and Related Metabolic Disorders,* 23, 801-809.

Receveur, O. & Kuhnlein, H. V. (1998). Benefits of traditional food in Dene/Metis communities. *International Journal of Circumpolar Health,* 57, 219-221.

Robinson, T. N. (2001). Television viewing and childhood obesity. *Pediatric Clinics of North America,* 48, 1017-1025.

Roemmich, J.N., Clark, P.A., Weltman, A., & Rogol, A.D. (1997). Alterations in growth and body composition during puberty. Comparing multi-compartment body composition models. *Journal of Applied Physiology,* 83, 927-935.

Rogol, A. D., Roemmich, J. N. & Clark, P. A. (2002). Growth at puberty. *Journal of Adolescent Health,* 31, 192 - 200.

Rosner, B., Prineas, R. Daniels, S.R. & Loggie, J. (2000). Blood pressure differences between blacks and whites in relation to body size among US children and adolescents. *American Journal of Epidemiology,* 151, 1007-19.

Sabiston, C.M., Sedgwick, W.A., Crocker, P.R.E., Kowalski, K.C. & Mack, D.E. (2007). Social physique anxiety in adolescence: an exploration of influences, coping strategies and health behaviors. *Journal of Adolescent Research,* 22, 78-101.

Salbe, A.D. & Ravussin, E. (2000). The determinants of obesity. In Bouchard, C. (Ed). *Physical Activity and Obesity*. Champaign: Human Kinetics.

Savva, S. C., Tornaritis, M., Savva, M. E., Kourides, Y., Panagi, A., Silikiotou, N., et al. (2000). Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *International Journal of Obesity,* 24, 1453 - 1458.

Schwimmer, J. B. (2003). Health-related quality of life of severely obese children and adolescents. *Journal of American Medical Association,* 289, 1813-1819.

Sellers, E.A.C., Singh, G.R. & Sayers, S.M. (2008). Large Waist but Low Body Mass Index: The Metabolic Syndrome in Australian Aboriginal Children. *Journal of Pediatrics,* 153, 222 – 227.

Serdula, M. K., Ivery, D., Coates, R. J., Freedman, D. S., Williamson, D. F., & Byers, T. (1993). Do obese children become obese adults? A review of literature. *Preventive Medicine,* 22, 167 - 177.

Seto, C. & Associates (2006). *Protecting Our Gifts and Securing Our Future. First Nations Children and Obesity: A Growing Epidemic.* Toronto: The Assembly of First Nations.

Sherar, L.B., Esliger, D.W., Baxter-Jones, A.D., et al. (2007). Age and gender differences in youth physical activity: does physical maturity matter? *Medicine and Science in Sports and Exercise,* 35, 830-35.

Shetty, P.S., Henry, C.J., Black, A.E., & Prentice, A.M. (2004). Energy requirements of adults: an update on basal metabolic rates (BMRs) and physical activity levels (PALs). *European Journal of Clinical Nutrition*, 50, S1123.

Shields, M. (2005). *Measured obesity. Overweight Canadian children and adolescents* (Catalogue no. 82-620-MWE200501). Ottawa: Statistics Canada.

Silverman, B.L., Rizzo, T., Cho, N.H., & Metzger, B.E. (1998). Long term effects of the intrauterine environment. *Diabetes Care, 2*1, B142–9.

Smith, C. & Rinderknecht, K. (2003). Obesity correlates with increased blood pressures in urban Native American youth. *American Journal of Human Biology,* 15, 78 – 90.

Spink, K.S., Chad, K., Muhajarine, N., Humbert, L., Odnokon, P., Gryba, C., et al. (2005). Intrapersonal correlates of sufficiently active youth and adolescents. *Pediatric Exercise Science,* 17, 18-29.

SPSS. Version 16.0, reference Guide. Chicago: SPPS Inc.

Srinivasan, S.R., Bao, W., Wattigney, W.A., & Berenson, G.S. (1996). Adolescent overweight Is associated with adult overweight and related multiple cardiovascular risk factors: the Bogalusa Heart Study. *Metabolism,* 45, 235-40.

Statistics Canada (2004). Aboriginal Peoples Survey 2001 - initial findings: Well-being of the non-reserve Aboriginal Population. Catalogue no. 89-589-XIE. Ottawa: Statistics Canada Aboriginal Peoples Survey 2. Available from:http://www.statcan.gc.ca/pub/89 589-x/89-589-x2003001-eng.pdf. Accessed October 29, 2009.

Statistics Canada (2002). *Statistics Canada 2001 Census Dictionary* (Ottawa, Ontario: Statistics Canada, 2002), catalogue no. 92-378-XIE.

Stein, C.J. & Colditz, G.A. (2004). The epidemic of obesity. *Journal of Clinical Endocrinology and Metabolism*, 89, 2522, - 2525.

Stensel, D.J., Gorely, T., & Biddle, S.J.H. (2008). Youth Health Outcomes. In: Smith, A.L. & Biddle, S.J.H. (Eds). *Youth Physical Activity and Sedentary Behavior.* Champaign: Human Kinetics; P. 31 - 57.

Strauss, R.S. & Knight, J. (1999). Influence of the home environment on the development of obesity in children. *Pediatrics*, 103, E85.

Story, M., Hauck, F.R., Broussard, B.A., White, L.L., Resnick, M.D., & Blum, R.W. (1994). Weight perceptions and weight control practices in American Indian and Alaska Native adolescents. A national survey. *Archives of Pediatrics & Adolescent Medicine,* 148, 567-571.

Story, M., Evans, M., Fabsitz, R.R., Clay, T.E., Holy Rock, B., & Broussard, B. (1999). The epidemic of obesity in American Indian communities and the need for childhood obesity-prevention programs. *American Journal of Clinical Nutrition,* 69, 747S - 754S.

Story, M., Stevens, J., Himes, J., Stone, E., Holy Rock, B., Ethelbah, B. & Davis, S. (2003). Obesity in American-Indian children: prevalence, consequences, and prevention. *Preventive Medicine*, 37, S3 - S12.

Stunkard, A.J., Harris, J.R., Pedersen, N.L. & McLearn, G.E. (1990). The body-mass index of twins who have been reared apart. *New England Journal of Medicine*, 322, 1483 1487.

Taylor, J.P., Evers, S. & McKenna, M. (2005). Determinants of healthy eating in children and youth. *Canadian Journal of Public Health,* 96, S20 - S26.

Thompson, A.M., Baxter-Jones, A.D., Mirwald, R.L., & Bailey, D.A. (2002). Secular trend in the development of fatness during childhood and adolescence. *American Journal of Human Biology*, 14**,** 669-679.

Thompson, A.M., Baxter-Jones, A.D.G., Mirwald, R.L., & Bailey, D.A. (2003). Comparison of physical activity in male and female children: does maturation matter? *Medicine and Science in Sports and Exercise,* 35, 1684 - 1690.

Tjepkema, M. (2006). Adult obesity. *Health Reports,* 17, 9 – 25.

Torrance, B., McGuire, K.A., Lewanczuk, R. & McGavock, J. (2007). Overweight, physical activity and high blood pressure in children: a review of the literature. *Vascular Health and Risk Management*, 3, 139-149.

Tremblay, M.S., Shields, M. Laviolette, M., Craig, C.L., Janssen, I. & Gorber, S.C. (2009). Fitness of Canadian children and youth: Results from the 2007-2009 Canadian Health Measures Survey. *Health Reports,* 21, 1-14.

Tremblay, M.S., Perez, C.E., Ardern, C.I., Bryan, S.N. & Katzmarzyk, P.T. (2005). Obesity, overweight, and ethnicity. *Health Reports,* 16, 23 - 32.

Tremblay, M.S. & Willms, J.D. (2000). Secular trends in the body mass index of Canadian children. *Canadian Medical Association Journal,* 163, 1429 - 1433.

Tremblay, M.S. & Willms, J.D. (2003). Is the Canadian childhood obesity epidemic related to physical inactivity? *International Journal of Obesity,* 27, 1100-1105.

Trifonopoulos, M. (1995). Anthropometry and diet of Mohawk schoolchildren in Kahnawake. Thesis. Montreal, QC: McGill University.

Trifonopoulos, M., Kuhnlein, H. V. & Receveur, O. (1998). Analysis of 24-hour recalls of 164 fourth- to sixth-grade Mohawk children in Kahnawake. *Journal of American Dietetic Association*, 98, 814 - 816.

van Lenthe, F.J., Van Mechelen, W., Kemper, H.C.G. & Post, G.B. (1998). Behavioral variables and development of a central pattern of body fat from adolescence into adulthood in normal-weight whites: the Amsterdam Growth and Health Study. *American Journal of Clinical Nutrition*, 67, 846-52.

Vartanian, L.R., Schwartz, M. B., & Brownell, K. D. (2007). Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *American Journal of Public Health,* 97.

Wang, Y.F. (2002). Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. *Pediatrics*, 110, 903-10.

Wang, Z. & Hoy, W.E. (2004). Body size measurements as predictors of type 2 diabetes in Aboriginal people. *International Journal of Obesity*, 28, 1580 – 1584.

Wang, J., Thornton, J.C., Bari, S., Williamson, B., Gallagher, D., Heymsfield, S.B., et al. (2003).Comparisons of waist circumferences measured at 4 sites. *American Journal of Clinical Nutrition*, 77, 379 - 84.

Warburton, D.E., Nicol, C. & Bredin, S.S. (2006). Health benefits of physical activity: the evidence. *Canadian Medical Association Journal*, 174, 801-809.

Weber J., Lytle, L., Gittelsohn, J., Cunningham-Sabo, L., Heller, K., Anliker, J. et al. (2004). Validity of self-reported dietary intake at school meals by American Indian children: the pathways study. *Journal of the American Dietetic Association*, 104, 746-752.

Weiss, R., Dziura, J., Burgert, T.S., Tamborlane, W.V., Taksali, S.E., Yeckel, C.W. et al. (2004). Obesity and the metabolic syndrome in children and adolescents. *New England Journal of Medicine*, 350, 2362-2374.

Whiting, S.J. & Shrestha, R.K. (1993). Dietary assessment of elementary school-age children and adolescents. *Journal of Canadian Dietetic Association*, 54, 196.

Willows, N.D. (2005). Overweight in First Nations children: prevalence, implications, and solutions. *Journal of Aboriginal Health,* 2, 76 – 86.

Wolever, T.M.S., Hamad, S., Gittelsohn, J., Hanley, A.J.G., Logan, A., Harris, S.B. et al. (1997). Nutrient intake and food use in an Ojibwa -Cree community in northern Ontario assessed by 24-hr dietary recall. *Nutrition Research,* 17, 603-618.

World Health Organization (2000). *Obesity: Preventing and Managing the Global Epidemic* (WHO technical report series no 894). Geneva: World Health Organization.

World Health Organization (2003). *Canadian Guidelines for Body Weight Classification in Adults*. Ottawa: Health Canada.

Young, T.K. (2003). Review of research on aboriginal populations in Canada: relevance to their health needs. *British Medical Journal*, 327, 419-422.

Young, T.K., Reading, J., Elias, B. & O'Neil, J.D. (2000). Type 2 diabetes mellitus in Canada's First Nations: status of an epidemic in progress. *Canadian Medical Association Journal*, 163, 561 - 566.

Young, K.T. (1996). Obesity central fat patterning and their metabolic correlates among the Inuit of the central Canadian Arctic. *Human Biology*, 68, 245 – 263.

Young, K.T. & Katzmarzyk, P.T. (2007). Physical activity of Aboriginal people in Canada. *Applied Physiology Nutrition and Metabolism*, 32, S148 – S160.

Young, T.K. & Sevenhuysen, G. (1989). Obesity in northern Canadian Indians: patterns, determinants and consequences. *American Journal of Clinical Nutrition*, 49, 786 – 793.

Young, R.S. & Rosenbloom, A.L. (1998). Type 2 (non-insulin dependent) diabetes in minority youth: conference report. *Clinical Pediatrics*, 37, 63-66.

Young, T. K., Dean, H. J., Flett, B., & Wood-Steinman, P. (2000). Childhood obesity in a population at high risk for type 2 diabetes. *Journal of Pediatrics*, 136, 365 - 369.

Young, T.K., Martens, P.J., Taback, S.P., Sellers, E.A. C., Dean, H.J., Cheang, M., et al. (2002). Type 2 Diabetes Mellitus in children: prenatal and early infancy risk factors among Native Canadians. *Archives of Pediatric and Adolescent Medicine*, 156, 651 655.

Yusuf, S., Hawken, S. & Ounpuu, S. (2005). Is waist-to-hip ratio a better marker of cardiovascular risk than body mass index? *Canadian Medical Association Journal*, 366, 1640-1649.

APPENDICES

APPENDIX A

Preliminary Report for Oskayak High School

OSKAYAK HIGH SCHOOL PRELIMINARY RESULTS

Sample Characteristics. A pilot study was conducted at the Oskayak high school to characterize the health behaviors of the students. Sixty one students (14 – 20 years; mean age 17.1 years) (25 M; 36 F), who self identified as either First Nations (97%) or Métis (3%), participated in this pilot study. At the time of the project, the students were currently living with: both parents (18.3%); mother only (35.0%); father only (3.3%); other family members (25.0%); alone (10.0%); with friends (1.7%); in a group home (1.7%); and with others (5.0%).

Nutrition. Although 40% of the youth believed they were consuming enough fruit and vegetables a day to achieve health benefits, less than 8% of the students consumed enough according to the national guidelines (Public Health Agency of Canada, 2007). The average consumption was approximately 3 servings per day (1.5 fruit; 1.5 vegetables). Findings also showed that no student ate breakfast on a regular basis - 43% said hardly ever/never; 21% said once a week; 36% said 2 – 3 times per week. We also investigated the consumption of "junk" food high in calories but low in nutritional value. For the purpose of this study, we defined one "junk food" as a regular size bag of chips, one can of pop or one regular size chocolate bar. Our findings indicated that on average, students at Joe Duquette consumed 4.4 servings of "junk food" per day.

Physical Activity. Using a previously validated and reliable physical activity questionnaire (Modifiable Activity Questionnaire for Adolescents (MAQ-A), our findings revealed that on average, students at Oskayak expended 6.7 KKD of physical activity per day, below the minimum recommendation of 8.0 KKD for optimal growth and development (Craig, Russell, Cameron & Beaulieu, 1999). Only 38% of the students stated that they believed they were active enough to receive health benefits.

Other Health behaviours and self-rated health. Less than 20% of the students did not smoke, with 73% of the sample smoking at least once a day (17% half a pack/day; 34% a pack or more/day. Fifty five percent of the students, however, had tried to stop smoking and fifty percent wanted to stop. Only thirty five percent of the students did not drink, and 53% of the youth reported using drugs to get high during the past 12 months.

Disease Awareness. 65% of the youth agreed that being physically active reduces the incidence of diabetes, cancer and cardiovascular disease and 66% agreed that eating fruits and vegetables reduces the incidence of diabetes, cancer and cardiovascular disease. Fifty percent of the students agreed that stopping tobacco usage reduces the incidence of diabetes, cancer and cardiovascular disease.

Familial Diabetes. Sixty one percent of the students reported that at least one member of their immediate family has been told by a nurse or doctor that they have diabetes.

APPENDIX B

Informative Letter

Dear ____________,

We hope you've had a great Christmas break filled with rest and relaxation! The reason we are writing this letter to you is to tell you about an exciting project taking place at the College of Kinesiology. The project, originally developed in partnership with Oskayak (formerly Joe Duquette) High School, is designed to promote healthy lifestyles for healthy body weights in Aboriginal children and youth. We have the opportunity to offer this project for another term and therefore would like to invite the youth from your school/community to participate sometime this term!

If your community is interested in this project, we invite you to contact us in person or over the email or telephone, to discuss the research intent of the project and collaborate on the activities and logistics of your involvement in this project. Following this discussion, your school/community would be invited to participate in a field trip to the College of Kinesiology at the University of Saskatchewan at a time that suits you. Participation in the field trip would allow the youth from your school/community to take part in a variety of physical activities offered at the new Physical Activity Complex, and with your consent, each student would also be invited to participate in our ongoing research project. Upon their (and their parents') consent, each student would be asked to complete a few short tests (e.g., a body scan to measure muscle, bone and fat levels, and physical activity, health and nutrition surveys) at the Physical Activity Complex. Collecting this information would really help us understand the growth and development trends and lifestyle patterns among Saskatchewan Aboriginal youth as they age – (i.e., are their physical activity levels, eating patterns, and body weights going up? going down? staying the same? And do the findings differ between boys and girls - as they get older?) This will help to inform all of us as to what kind of culturally specific programs, resources, and services we need to develop for these youth. Given that the research part of this project will take only a portion of the day, youth would also have the opportunity to tour around the University and the College of Kinesiology to learn and participate in some fun activities. We are open and encourage any suggestions you might have in how we can best carry out this project!

We welcome any Aboriginal youth who wish to participate in this project and to thank the youth and you for helping us with this project, we would provide an incentive gift (i.e., money to be used for your school for things such as equipment). In addition, funds to assist in the cost of your travel (i.e., to cover your transportation, lunch, etc.) will be available upon your request. We have attached an information sheet and consent form for your perusal, should you want more specific project information. Our contact information is also enclosed.

We look forward to working with you, and hope that you and the youth in your community will consider visiting Kinesiology. We appreciate that this term will be very busy for you, and so we will follow up with you should we not hear back from you over the next couple of weeks.

Sincerely yours,

Karen Chad, Ph.D.
College of Kinesiology

Kristal Anderson
College of Kinesiology

APPENDIX C

Promotional Poster

Want to learn more about your health?

If your answer is YES, then come join us for an exciting project offered by the College of Kinesiology at the U of S! The project involves having a cool body scan that will measure your muscle, bone, and fat and then answering some physical activity and nutrition surveys that will help you learn more about the physical activities your body can do and the foods you can eat to improve your health and reduce your risk of diabetes.

The session will take about an hour to complete and is free! To thank you for your participation, your school will be given some special prizes to share with you!

To participate in this project, you must be within 8 – 17 years of age and complete a consent form signed by both you and your parent/guardian. For more information, please talk to your school teacher (insert contact name here).

APPENDIX D

Certificate of Ethics Approval

University of Saskatchewan
Behavioural Research Ethics Board (Beh-REB)

30-Mar-2006

Certificate of Approval
Study Revisions

PRINCIPAL INVESTIGATOR
Karen Chad

DEPARTMENT
Kinesiology

BEH#
Beh 04-96

STUDENT RESEARCHER(S)
Kristal Anderson, Brenda Bruner (Lindstrom)

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED (STUDY SITE)
University of Saskatchewan
Saskatoon SK

SUB-INVESTIGATOR(S)
Sylvia Abonyi
Adam Baxter-Jones
Bonita Beatty
Roland F. Dyck
Evelyn Peters
Susan J. Whiting

SPONSOR
CANADIAN INSTITUTES OF HEALTH RESEARCH (CIHR)

TITLE
thern LITES: Northern Lifestyle Initiatives Targeting the Environments. Development of Childhood Body Composition

CURRENT APPROVAL DATE
27-May-2004

CURRENT RENEWAL DATE
01-May-2006

CERTIFICATION UPDATE
Addition of Student Researchers

APPROVED ON
30-Mar-2006

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the proposed revisions to your study. The revisions were found to be acceptable on ethical grounds.

The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Research Ethics Board consideration in advance of its implementation.

ONGOING REVIEW REQUIREMENTS

The term of this approval is five years, but the approval must be renewed on an annual basis. In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions:

http://www.usask.ca/research/ethical.shtml

ase send all correspondence to:

Ethics Office
University of Saskatchewan
Room 306, Kirk Hall, 117 Science Place
Saskatoon, SK S7N 5C8
Phone: (306) 966-2084 Fax: (306) 966-2069

APPENDIX E

Participant Assent Form

ASSENT FORM (YOUTH PARTICIPANT)

Healthy Lifestyles for Healthy Body Weights Project

We would like to ask for your help with a project that is being carried out by your school (insert name of the school) and the University of Saskatchewan. The purpose of this project is to encourage healthy eating and physical activity behaviors and promote healthy body weights among the students and staff at your school. While participation is optional, we hope that all youth will agree to participate. The findings from this project will provide important information in developing community based programs aimed at reducing obesity and maintaining healthy body weights, ultimately preventing diseases such as diabetes.

If you decide to volunteer, your role is to take three short tests that will measure your muscle, bone and fat, and complete two surveys regarding the physical activities you are involved in and the kind of foods you to eat. One additional survey will ask you questions about your health behaviors and how often you've moved. All of the testing will be carried out on the same day by a qualified lab technician and will follow standard procedures performed at the Physical Activity Complex in the College of Kinesiology. The body composition testing and completion of the surveys will take about one hour in total to complete and will be provided free to you.

Participation is completely voluntary and you can withdraw at any time. Feedback will be given to you during the entire project, as there will be an assistant with you the entire time. You will be encouraged to ask questions if you don't understand something that you are asked to do. If you need help in reading and completing the questionnaires, an assistant will be happy to assist you by verbally administering the questionnaires.

During the measurement of muscle, bone and fat, you will be exposed to a small amount of radiation. However, this amount is less than you would receive from a short airplane flight. The benefits offered to you if you decide to participate in this study include increased knowledge of your health in terms of your fat, muscle, and bone, and nutritional and physical activity patterns. It is expected that the information gained by you in terms of your health will outweigh the minor risk associated with the procedures involved.

The results of this project will be completely anonymous because you will not have to put your name on any of the surveys, and only the group results will be reported. All the information provided through the surveys and the body tests will be confidential and will be stored in a locked office on the University Campus for a minimum of five years after the completion of the project. If you would like, we can give you a copy of the questionnaires to look over before making your decision about the study. If you begin the project and then decide you do not want to continue, you may withdraw at any time, for any reason, without penalty or without causing anyone to be upset.

With your permission and your parent's permission, the results will be used to help develop physical activity, nutrition, and body composition measurement tools for Aboriginal youth. If you and your parent decide that you would like to be a part of this project, please complete the attached form. If you or your parent has any questions or concerns about this study, please do not hesitate to contact Dr. Karen Chad (966-1071) at any time.

Students Please Read and Sign Your Consent

I________ voluntarily consent to participate in the project: Healthy Lifestyles for Healthy

Body Weights Project.

I have discussed this project and consent form with my parents/guardians. I understand the purpose of the project and my involvement, and that I have the option to withdraw at any time without penalty of any sort. I also agree that if I withdraw, any data that I have contributed will be destroyed. My information will be used for research purposes only, and any details that may reveal who I am will not be included in study reports and presentations. If me or my caregiver has any questions, I may call the Office of Research Services (966-2084) at the University of Saskatchewan. I have been given a copy of this form to keep.

Participants Signature:____________________________________Date:_____________

If you have any questions or concerns about this study, please do not hesitate to contact Dr. Karen Chad at any time at the address below.

- -

Researcher's Signature ___________________________________ Date_____________

The University of Saskatchewan Advisory Committee on Ethics in Behavioral Sciences Research approved this research project in April 2004.

Dr. Karen Chad
Principal Investigator
Saskatoon *in motion*
College of Kinesiology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 5B2
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Fax: 306-966-6502
Email: karen.chad@usask.ca

APPENDIX F

Parental Consent Form

CONSENT FORM (PARENTS)

Healthy Lifestyles for Healthy Body Weights Project

We would like to ask for your son or your daughter's assistance with a project that is being carried out by your school (insert name of school) and the University of Saskatchewan. The purpose of this project is to encourage healthy eating and physical activity behaviors to promote healthy body weights and prevent diabetes among the students and staff at your school. While participation is optional, we hope that all youth will agree to participate. The findings from this project will provide important information in developing community based programs aimed at reducing obesity and maintaining healthy body weights, ultimately preventing diseases such as diabetes.

If your son or your daughter decides to volunteer, his/her role is to take part in three short tests that will measure muscle, bone and fat, and complete two surveys regarding the physical activities they are involved in and the kind of foods they like to eat. Each youth will also be asked to fill in a health survey that asks about their health behaviors and migration patterns. All of the measurements will be carried out on the same day by qualified personnel and will follow standard procedures performed at the Physical Activity Complex in the College of Kinesiology. The body composition testing and completion of the surveys will take about one hour in total to complete and will be provided free to your child.

Participation is completely voluntary and your child will be informed that they can withdraw at any time. Your son or daughter will be encouraged to ask questions during completion of the surveys or the body composition testing if they need clarification, as there will be an assistant present at all times to give them feedback. If your child needs assistance in reading and completing the surveys, an assistant will be happy to help them by verbally administering the questions.

During the measurement of muscle, bone and fat, your son or daughter will be exposed to a small amount of radiation. However, this amount of radiation is less than that received from a short airplane flight. The benefits offered to those youth participating are an increased knowledge of their health as reflected by the healthy body weight, nutrition, and physical activity sessions. It is expected that the information gained by your child in terms of their health will outweigh the minor risk associated with the procedures involved.

All the information provided through the surveys and the body composition tests will be confidential and will be stored by Dr. Karen Chad in a locked office on the University Campus for a minimum of five years after completion of the project. Upon request, you and your child will be given a copy of the surveys to peruse. If your son or daughter wishes, he/she may withdraw at any time, for any reason, without penalty, or without causing anyone to be upset.

If you and your son or daughter decides that he/she would like to be a part of this project, please complete the attached form. If you or your son or daughter has any questions or concerns, please do not hesitate to contact Dr. Karen Chad (966-1071) at any time.

This research is supported by a grant obtained from the Canadian Institutes for Health Research.

PARENTS/GUARDIANS PLEASE READ and SIGN YOUR CONSENT

I have read and understood the purpose of this project and my son's/daughter's involvement. I am aware that my son/daughter will remain anonymous throughout the project and in any written results. I am aware that my son/daughter has the right to withdraw at any time without penalty. If I have any questions or concerns I can contact Dr. Karen Chad (966-1071), or if I wish to clarify the rights of my son/daughter as a research participant, I may call the Office of Research Services (966-2084). I have received a copy of the consent letter for my records.

I, ____________________________ give permission to allow ____________________

to participate in the project conducted by the College of Kinesiology.

Signature ____ Date ______________

- -

Dr. Karen Chad
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Phone: 306-966-1071
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APPENDIX G

Bone Densitometry (DXA) Form

Dept. of Nuclear Medicine
Royal University Hospital

Bone Densitometry Research
Registration Form

Name________________________ Subject#__________Date__________

Address_____________________ City____________Study Code_________

Postal Code________Phone___________ DOB______________
(mm-dd-yyyy)

Sask. Health #_______________RUH (MRN)#______________
(9 digits) (6 digits)

Family Physician_______________________ Send results Y N

....

Gender M F LMP_________ Pregnant Y N Handedness R L

Weight_______Height________ Hip or Spine surgery Y N_____________
lb / kg in / cm

X-Rays in past 7 days Y N ___________

....

Procedure: Circle application(s)

Hologic QDR: 2000 4500 Upgrade Discovery C

AP/LATERAL:	**LUMBAR:**	**HIP:**	**WHOLE BODY:**	**FOREARM:**
array spine	array	R / L	single beam	R / L
fast array spine	turbo array	array	array	
single beam spine	fast array	fast array hip	infant whole body	
hi-res array	hi-res array	single beam hip		
fast lateral				
hi-res lateral				

Notes/Comments:____
____
____

Bdregform2JAN03

APPENDIX H

Anthropometric Data Sheet

ID:_______________]

University of Saskatchewan
College of Kinesiology

Body Composition

ANTHROPOMETRY

Trial #	**Height** (cm)	**Sit Height** (cm)	**Weight** (kg)	**Waist Circumference** (cm)
1				
2				
3				
Average				

APPENDIX I

Physical Activity Questionnaire for Children/Adolescents (PAQ-C/PAQ-A)

[ID:_______________]

My Physical Activity

We are trying to find out about your level of physical activity from *the last 7 days* (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like skipping, running, or climbing.

Remember:
A. There are no right and wrong answers — this is not a test!
B. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 or more
Skipping	❍	❍	❍	❍	❍
Rowing/canoeing	❍	❍	❍	❍	❍
In-line skating	❍	❍	❍	❍	❍
Rugby	❍	❍	❍	❍	❍
Walking for exercise	❍	❍	❍	❍	❍
Bicycling	❍	❍	❍	❍	❍
Jogging or running	❍	❍	❍	❍	❍
Aerobics	❍	❍	❍	❍	❍
Swimming	❍	❍	❍	❍	❍
Baseball, softball	❍	❍	❍	❍	❍
Dance	❍	❍	❍	❍	❍
Wrestling	❍	❍	❍	❍	❍
Badminton	❍	❍	❍	❍	❍
Gymnastics	❍	❍	❍	❍	❍
Soccer	❍	❍	❍	❍	❍
Street hockey	❍	❍	❍	❍	❍
Volleyball	❍	❍	❍	❍	❍
Floor hockey	❍	❍	❍	❍	❍
Basketball	❍	❍	❍	❍	❍
Track and field	❍	❍	❍	❍	❍
Weight training	❍	❍	❍	❍	❍
Martial arts	❍	❍	❍	❍	❍
Ice skating	❍	❍	❍	❍	❍
Ice hockey/ringette	❍	❍	❍	❍	❍
Other:____________________	❍	❍	❍	❍	❍

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)
   - ❍ I don't do PE
   - ❍ Hardly ever
   - ❍ Sometimes
   - ❍ Quite often
   - ❍ Always

3. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)
   - ❍ Sat down (talking, reading, doing schoolwork)
   - ❍ Stood around or walked around
   - ❍ Ran or played a little bit
   - ❍ Ran around and played quite a bit
   - ❍ Ran and played hard most of the time

4. In the last 7 days, what did you normally do at *recess?* (Check one only.)
   - ❍ Sat down (talking, reading, doing schoolwork)
   - ❍ Stood around or walked around
   - ❍ Ran or played a little bit
   - ❍ Ran around and played quite a bit
   - ❍ Ran and played hard most of the time

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)
   - ❍ None
   - ❍ 1 time last week
   - ❍ 2 or 3 times last week
   - ❍ 4 times last week
   - ❍ 5 times last week

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)
   - ❍ None
   - ❍ 1 time last week
   - ❍ 2 or 3 times last week
   - ❍ 4 or 5 last week
   - ❍ 6 or 7 times last week

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)
   - ❍ None
   - ❍ 1 time
   - ❍ 2 — 3 times
   - ❍ 4 — 5 times
   - ❍ 6 or more times

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

❍ All or most of my free time was spent doing things that involve little physical effort
❍ I sometimes (1 — 2 times last week) did physical things in my free time
(e.g. played sports, went running, swimming, bike riding, did aerobics)
❍ I often (3 — 4 times last week) did physical things in my free time
❍ I quite often (5 — 6 times last week) did physical things in my free time
❍ I very often (7 or more times last week) did physical things in my free time

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit (1-2)	Medium (3 – 4 times)	Often (4 – 5)	Very often (5+)
Monday	❍	❍	❍	❍	❍
Tuesday	❍	❍	❍	❍	❍
Wednesday	❍	❍	❍	❍	❍
Thursday	❍	❍	❍	❍	❍
Friday	❍	❍	❍	❍	❍
Saturday	❍	❍	❍	❍	❍
Sunday	❍	❍	❍	❍	❍

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ☐ If Yes, what prevented you? ___________________

No ☐

APPENDIX J

Modifiable Activity Questionnaire for Adolescents (MAQ-A) and Screen Time Questions

Physical Activity During the Past Month

<u>A. Let's start with activities that you Signed Up Or Registered For:</u> Examples of these kinds of activities may include playing on a school, community or zone team, taking dance or swimming lessons, or attending an exercise class.

1. Circle all of the activities that you participated in the PAST MONTH that you had to sign up or register for.
   <u>Do not include time spent in school physical education classes.</u>

Aerobics	Dance	Martial Arts	Softball	Track
Archery	Diving	Racquetball	Speed Skating	Volleyball
Badminton	Figure skating	Ringette	Street/Flr	Wrestling
Baseball	Football	Rowing	Hockey	Yoga
Basketball	Gymnastics	Rugby	Swimming	Other
Bowling	Ice hockey	Skiing Downhill	Syncro	_______________
Boxing	Kickboxing	Skiing-Xcountry	Taebo	
Curling	Lacrosse	Soccer	Tennis	

2. List **each** activity that you circled above in the "Activity" box below.
3. For **each** activity, record the number of times you participated **each** week for the last 4 weeks.
4. For **each** activity, estimate the average number of minutes that you spent participating **each** time. Record this in the last box. Only report the time that you were **<u>actively participating in the activity</u>**.
5. For each activity, record the intensity as **Light** (light change from normal breathing), **Medium** (above normal breathing), or **Heavy**.
6. For **each** activity, record where the activity takes place, at **<u>School (S), Park (P), Facility (F), or in or out of your Neighborhood.</u>**

ACTIVITY	**Number of Times Doing the Activity**				**Ave # of <u>Minutes</u> You Were Active in the Activity EACH Time**	**Intensity** **L**=Light **M=Medium** **H**=Heavy	*Location* **S**= School **P**= Park **F**= Facility	*Neighborhood* **W** = Within Neighborhood **O** = Outside Neighborhood
	Last Week	**2 wks ago**	**3 wks ago**	**4 wks ago**				

<u>B. Now think of all the activities that you participated in the past month that You *Did Not* Need To Sign Up Or Register For:</u> Examples of these kinds of activities may include walking, biking, jogging, skateboarding, swimming, basketball game.

1. Circle all of the activities that you participated in the **PAST MONTH** that you **DID NOT** have to **Sign Up or Register For**. <u>Do not include time spent in school physical education classes</u>.

Aerobics	DanceAboriginal	Ping Pong	Skipping	UltimateFrisbee
Badminton	Dance-Break	Racquetball/Squash	Snowboarding	Volleyball
Baseball	Football	Ringette	Soccer	Walking
Basketball	Garden/YardWork	Rowing	Softball	Wall Climbing
Biking-	Golf	Rugby	Street/Floor hockey	Weight training
Outdoors	Gymnastics	Running	Swimming	Wrestling
Biking-	Hacki sac	Shoveling	Diving	Yoga
Stationary	Hiking	Skateboarding	Swimming-Laps	Other __________
Bowling	HorsebackRiding	Skating-Ice	Swim-Leisure	
Boxing	Ice hockey	Skating-Inline	Taebo	
Curling	MartialArts/Kick	Skiing-Downhill	Tennis	
Dance	box	Skiing-X Country	Trampoline	

2. List **each** activity that you circled above in the "Activity" box below.
3. For **each** activity, record the number of times you participated **each** week for the last 4 weeks.
4. For **each** activity, estimate the average number of minutes that you spent participating **each** time. Only record time that you were **<u>actively participating in the activity</u>**.
5. For each activity, record the intensity as **Light** (light change from normal breathing), **Medium** (above normal breathing), or **Heavy**.
6. For **each** activity, record where it took place: at **<u>Home (H), School (S), Park (P), Facility (F) or in or out of your Neighborhood.</u>**

ACTIVITY	**Number of Times You Did the Activity**				**Ave # of <u>Min</u> You Were Active in the Activity EACH Time**	***Intensity*** **L**=Light **M**=Medium **H**=Heavy	***Location*** **H**= Home **S**= School **P**= Park **F**= Facility	***Neighborhood*** **W** = Within Neighborhood **O** = Outside Neighborhood
	Last Week	**2 wks ago**	**3 wks ago**	**4 wks ago**				

SCREEN TIME QUESTIONS:

1. How many hours a day do you watch television or DVD/VCR videos?

a. Weekdays
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

b. Weekend
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

2. How many hours a day do you play video games (e.g., Xbox, Playstation, Computer)?

a. Weekdays
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

b. Weekend
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

3. How many hours a day are you on the computer or Internet (e.g., email, MSN, surfing)?

a. Weekdays
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

b. Weekend
□ None □1 hour or less □ 1 to 2 hours □ 2 to 3 hours □ 3 to 4 hours □ 4+ hours

APPENDIX K

24-Hour Dietary Recall

ID:________________]   Researcher: _____

Nutrition

PLEASE LIST every FOOD and DRINK the student ate yesterday

Time	**Food Items**	**Type & Preparation**	**Amount**	**Brand Name or Where Bought**
EXAMPLE	CEREAL	CORN FLAKES	1 cup	Kellogs
Morning				
Mid-morning				
Noon Meal				

Time	Food Items	Type & Preparation	Amount	Brand Name or Where Bought
Midday				
Evening Meal				
Before Bed				

1. Was this intake usual? Circle one: Yes No (*if No, explain why:* ______________________________)
2. Do you take any vitamin or mineral supplements? ❒Yes ❒No If Yes, please specify (supplement, brand name, dose, amount taken)

- Supplement 1 ____
- Supplement 2 ____
- Supplement 3 ____

3. How often do you eat breakfast? (at least toast and juice or cereal?)

☐ Hardly ever/never ☐ 2-3 days a week ☐ Once a week
☐ 4 – 6 days a week ☐ Every day or almost every day

APPENDIX L

Demographic Questionnaire

[ID : ____________]

My Health

Please be honest – your answers are private and we will make sure that no one will know who filled in this survey. No one from your school or community will find out what you write. Thank you!

1. Which Aboriginal group do you belong to: First Nations, Metis, or Inuit?
   - ❒First Nations Please specify (e.g. Cree, Dene) ____________
   - ❒Metis
   - ❒Inuit
   - ❒None

2. Who do you presently live with?
   - ❒Both parents (biological or adopted)
   - ❒Mother only
   - ❒Father only
   - ❒Other family members (e.g., a grandparent, etc.)
   - ❒Alone
   - ❒With friends
   - ❒Room and board
   - ❒Group home/foster home
   - ❒Other

3. In your opinion, would you say your health is (please check the one response that best describes you):
   - ❒Excellent
   - ❒Very good
   - ❒Good
   - ❒Fair
   - ❒Poor

On a scale from 1 to 5, with 1 being "not at all agree" and 5 being "strongly agree", what is your agreement with the following statements:

4. Being physically active helps prevent diabetes, cancer, and heart disease.

1	2	3	4	5
Not at all Agree		Don't Know		Strongly Agree

5. Eating fruits and vegetables helps prevent diabetes, cancer, and heart disease.

1	2	3	4	5
Not at all Agree		Don't Know		Strongly Agree

6. Stopping tobacco usage helps prevent diabetes, cancer, and heart disease.

1	2	3	4	5
Not at all Agree		Don't Know		Strongly Agree

7. Do you smoke cigarettes?
   - ❒Not at all
   - ❒Once in a while
   - ❒1-5 times a day
   - ❒Half a pack a day
   - ❒A pack or more a day

8. Do you use smokeless tobacco (chewing tobacco, snuff, etc.)?
   - ❒Not at all
   - ❒Once in a while
   - ❒1-5 times a day
   - ❒Half a pack a day
   - ❒A pack or more a day

9. How often do you drink anything alcoholic such as beer, wine or liquor?

❐Never ❐Once a week
❐About once a month ❐2-3 times a week
❐2-3 times a month ❐Every day

10. Have you used any of these drugs to get high during the past 12 months?

	None	1-2	3-9	10-19	20-49	50 or more
Uppers	❍	❍	❍	❍	❍	❍
Cocaine	❍	❍	❍	❍	❍	❍
Crack	❍	❍	❍	❍	❍	❍
Sniffing-glue, gas, solvents	❍	❍	❍	❍	❍	❍
LSD (acid)	❍	❍	❍	❍	❍	❍
Other psychedelic	❍	❍	❍	❍	❍	❍
PCP	❍	❍	❍	❍	❍	❍
Ketamine (Special K)	❍	❍	❍	❍	❍	❍
Heroin	❍	❍	❍	❍	❍	❍
Other narcotics (e.g.Codeine)	❍	❍	❍	❍	❍	❍
Adrenochromes (Bovays)	❍	❍	❍	❍	❍	❍
Methamphetamines	❍	❍	❍	❍	❍	❍
Ecstacy (XTC, MDMA)	❍	❍	❍	❍	❍	❍
Crystal Meth	❍	❍	❍	❍	❍	❍
Marijuana	❍	❍	❍	❍	❍	❍
Other: (please specify)	❍	❍	❍	❍	❍	❍

____

11. Are you currently taking any medications?

❐No ❐Yes (If yes, what medication(s) are you taking and what are they for?)

Medications: For:

____________________ ____________________
____________________ ____________________

12. Do you have diabetes or high blood sugar? (As told by a doctor or other health professional)

❐Yes → At what age were you first told that you had diabetes? ____ (years)
❐No

13. Does anyone in your immediate family have diabetes (as told by a doctor, or other health professional)?

❐Yes → What relation are they to you? ______________________
❐No

14. Have you lived in this city, town or community all your life? ❐Yes ❐No ❐I don't know

15. How many times, if any, have you moved in the past five years? Do not include moves within the same city, town, or community.

❐None ❐1-2 times ❐3 – 4 times ❐ 5 or more times

16. How many times, if any, have you moved in the past five years? Include moves within the same city, town, or community.

❐None ❐1-2 times ❐3 – 4 times ❐ 5 or more times

17. FOR FEMALES ONLY. Are you currently pregnant?

❐Yes ❐No ❐I don't know

APPENDIX M

Classification of Aboriginal Groups in Canada

Classification of Aboriginal Groups in Canada

The Canadian Constitution (section 35) recognizes *three Aboriginal groups*:

1. Indian people and legal categories:
    a. Status Indian
    b. Treaty Indian
    c. Non-Status Indian
2. Inuit
3. Métis

Language Families

- Algonkian – Blackfoot, Cree, Micmac, Ojibwa
- Athapaskan – Sarcee and Dene
- Eskimo-Aleut - Inuktitut
- Siouan
- Wakashan
- Salishan
- Iroquoian - Mohawk
- Tsimshian
- Haida
- Tlinigit
- Kutenai

Culture Areas

Culture areas are based on the geographical location of different groups and tend to be linked to modes of existence. Groups within specific culture areas tend to share the same language (language and culture overlap). Culture areas also tend to share similar internal organization among its member groups.

Recognized Culture Areas in Canada (n = 7):

- Arctic: Inuit
- E. Subarctic: Ojibwa, Algonkins, Cree, Montagnais, Naskapi, Micmac (some)
- Easter woodlands: Micmac, Iroquois, Huron, S. Ontario and South of the Great Lakes
- Plains: Plains Cree, Blackfoot Confederacy, Ojibwa (Saulteaux) and Tsun -Tina
- Plateau: Interior Salish, Kootenay, Carrier, Tagish, Taltan, Okanagan, Thompson, Nicola
- NW Coast: Haida, Nootka, Kwakiutl, Salish, Tsimshian, Tlingit
- W. Subarctic: Gwich-in, Beaver, Tagish, Hare, Dogrib, Chipewyan, and Slavey