THE EFFECTS OF A GYMNASTICS PROGRAM ON
EARY CHILDHOOD (4-6 YRS) BODY
COMPOSITION DEVELOPMENT

A Thesis Submitted to the College of
Graduate Studies and Research
In Partial Fulfillment of the Requirements
For the Degree of Masters of Science
In the College of Kinesiology
University of Saskatchewan
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ABSTRACT

The dramatic rise in health care and economic costs as well as increases in morbidity and mortality related to lifestyle behaviors and non-communicable diseases have resulted in an increasing emphasis on research and intervention initiatives aimed at primary prevention. As there is growing evidence that the antecedents of adult diseases such as obesity and osteoporosis have roots in early childhood, physical activity interventions in early childhood (4 to 6 years of age), which has been identified as a critical period, may influence the development of fat and bone mass at this young age and have a potential impact on adolescent and young adult health status and thus improve population health. The intent of this study was to investigate the effects of structured physical activity, specifically early involvement in gymnastics, on early childhood body composition development.

Sixty three (25 male and 38 female) 4 to 6 year old children participating in gymnastics programs were compared to 95 control (49 male and 46 female) children. Anthropometric measurements included height, weight, BMI, waist circumference, and skinfold thickness. Dual energy x-ray absorptiometry (DXA) was used to measure whole body bone density and fat mass. Physical activity, physical inactivity, dietary intake, and birth weight of the participants as well as parental heights and weights were also obtained.

No significant differences were found, at any age, between the groups in height, weight, BMI, waist circumference, skinfold thickness, physical activity, physical inactivity, dietary intakes, and birth weight or in parental heights and weights ($p>0.05$).
Additionally, there were no significant differences in fat and bone parameters once the confounders of age and size were controlled ($p>0.05$).

This investigation found that young children entering a gymnastics program did not differ in either bone mass or fat mass compared to controls. This was surprising as differences in these parameters have been found in adolescent gymnasts. Thus my results indicate that the potential effects of gymnastics training may have not yet manifested themselves. To answer this question longitudinal measures are required to ascertain whether the body composition differences observed in adolescent gymnasts are due to prolonged exposure to gymnastics involvement.
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DEDICATION

This thesis is dedicated to my parents Martin and Cheryl for their unending support and encouragement and for always believing in me. They have endured all the ups and downs the process of writing a thesis yields, from tears and curses at computers to the joy of producing a final product. And finally, a special thank-you to my mother for her numerous rounds of proof reading, I know you’ve learned more than you ever wanted about gymnastics and body composition. I appreciate all the time and energy you have devoted to guiding and aiding me to this place in my educational journey – thank you!
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1.0 INTRODUCTION

The dramatic rise in health care and economic costs related to lifestyle behaviors and non-communicable diseases has resulted in an increasing emphasis on research and intervention initiatives aimed at primary prevention (Kemper, 1985). Research programs and intervention strategies in health promotion are needed across the lifespan; however, childhood and adolescence are particularly important. It has been postulated that the earlier health promotion and preventative action are taken in an individual’s development, the greater the chances of sustaining long-term healthy living habits thereby reducing the risk of adult diseases. There is growing evidence that the antecedents of adult diseases such as obesity and osteoporosis have their roots in early childhood (Must & Strauss, 1999; Taylor, Goulding, Lewis-Barned, & Williams, 2004; Cumming, Black, Nevitt, Browner, Cauley, Ensrud, et al., 1993 & Proctor, Adams, Shaffrath, & Van Loan, 2002). Therefore, interventions that influence the attainment of fat and bone mass in childhood have the potential to have an impact on adult health status and overall population health.

Physical activity and sport are known to positively affect childhood body composition (fat and bone tissue) development (Bar-Or & Baranowski, 1994; Garaulet, Martinez, Victoria, Perez-Llamas, Ortega, & Zamora, 2000; Maffeis, Zaffanello, Pinelli, & Schutz, 1996); however, there are also some concerns about the potential negative effects that intensive physical training may have on a child’s growth and development. For example, it has been suggested that intense training at a young age adversely affects the growth and maturation of young gymnasts (Weinmann, Blum, Schwidergall, &
Bohles, 1999; Daly, Rich, Klein, & Bass, 2000; Caine, Lewis, O’Conner, Howe, & Bass, 2001; Daly, Rich, & Klein, 1998).

The effect of physical activity and exercise on the growth and development of children has been an area of interest for over 100 years. Studies performed in the early 20th century suggested that physical activity in males had a stimulatory effect on stature growth; for example young male athletes were observed to be taller and stronger than their age matched non-athletic peers. More recently; however, much of the literature suggests that the reason some elite young athletes are taller and stronger than their peers is not due to the stimulatory effect of training, but more likely related to the timing of maturation; that is, early maturers may self-select into sports where their increased size and strength are advantageous such as in basketball and football (Malina, 1994; Theintz, Howald, Allemann, & Sizonenko, 1989; Malina 1998; Baxter-Jones, Helms, Maffulli, Preece, & Preece, 1995).

In contrast, the opposite is likely true for the sport of gymnastics where a small light weight physique is favorable for performance success. Confounding this, has been the suggestion that the high intensity and volume required for elite gymnastics training at an early age may adversely affect a child’s growth and development. High intensity training from an early age has been suggested to delay or retard the growth spurts in gymnasts’ lower extremities resulting in reduced stature (Theintz, Howald, Weiss & Sizonenko, 1993). In contrast, it has been suggested that the short stature observed in elite gymnasts is partly due to selection of individuals with reduced leg length and that it is the trunk length rather than leg length that is being compromised (Bass, Bradney,
Pearce, Hendrich, Inge, Stuckey et al., 2000, & Caine, et al., 2001). Thus, the influence of intensive gymnastics training on growth is still controversial.

The question as to whether gymnastics training has positive or adverse effects on the growth and development of young children, has received considerable attention in the popular press. In some instances, such as the studies presented above, gymnastics training has been associated with negative impacts on children’s health; however, participation in gymnastics training has also been shown to have many positive effects on body composition development, including increased bone mineral accrual, increased lean tissue development and decreased fat mass development (Nickols-Richardson, O’Conner, Shapses and Lewis, 1999; Laing, Massoni, Nickols-Richardson, Modlesky, O’Conner, & Lewis, 2002). Since the antecedents of adult diseases, such as cardiovascular disease, obesity, diabetes and osteoporosis, have been linked to body composition development in childhood (Raine, 2004), gymnastics training in early childhood may have positive effects on fat and bone development thereby reducing the risk of adult diseases later in life. Therefore, the aim of this study was to determine the effects of gymnastics training on early childhood body composition development. I hypothesized that children involved in gymnastics would have lower fat mass and higher bone mass compared to a control population.
2.0 LITERATURE REVIEW

2.1 Introduction

The goal of primary prevention for non-communicable diseases such as obesity and osteoporosis has been gaining in momentum and popularity; strategies to accomplish this goal are being investigated with the development of fat mass and bone mass in childhood becoming a primary focus.

The following literature review will examine the current “obesity epidemic” and why it is a cause for concern. A description of fat composition, changes in composition due to normal growth and development, and the critical periods of fat deposition will be described as background to help explain how physical activity, and gymnastics training specifically, can affect fat mass development in children. The potential impact of these activities on the childhood obesity epidemic will also be discussed.

In addition, the growing burden of osteoporosis on the health care system will be examined as a rationale for the positive effect of gymnastics on bone mineral accrual. Bone composition, changes in bone due to normal growth and development, and bone adaptation will be described to help explain how physical activity, and specifically gymnastics training, affects bone development in children. The potential impact of gymnastics on the occurrence of osteoporosis later in life will also be discussed.

2.2 The Obesity Epidemic

The obesity “epidemic” is of global proportions affecting both developing and industrialized nations including Canada (Tremblay & Willms, 2000). Health professionals are becoming increasingly concerned with regard to the rise in rates of obesity (in most population studies obesity is defined using an indirect measure of fat
mass, body mass index (BMI), an index of body mass (kg) in relation to height (m²)); however, the level of excess fat mass necessary to be classified as obese is still a source of some debate. Perhaps most alarming is the fact that the proliferation of obesity is not confined to the adult population but, rather, is being seen in younger generations as well. In general, children with a BMI greater than 85% of their gender and age matched reference standards are defined as overweight and children with a BMI > 95% of normal reference standards are classified as obese (Vignerova, Lhotska, & Blaha, 2001; Cole, Bellizzi, Flegal, & Dietz, 2000; Tremblay & Willms, 2000). According to some experts, the current generation of children is likely to have a shorter life expectancy than their parents as a result of obesity (Jain, 2004). In the United States, 25% of children are considered obese; this is almost a 20% increase in the prevalence of obesity over a 10-year period (Bar-Or, Foreyt, Bouchard, Brownell, Dietz, Ravussin, et al., 1998). The prevalence of overweight American preschool children between 1988-1994, using BMI above the 95% percentile as the cut point, was 2.1% and 4.8% in 2 year old and 3 year old boys and girls, respectively, and 5% and 10.8% in 4 and 5 year old boys and girls, respectively (Ogden, Troiano, Brefi fel, Kuczmarskie, Flegal, & Johnson, 1997). The fact that the incidence of overweight children is twice as prevalent among 4 and 5 year old children compared with 2 and 3 year old children suggest the origins of the problem begin early in life and are compounded over time. Most studies; however, have concentrated on prevalences in older children. In Canada, between 1981 and 1996 the occurrence of overweight children aged 7-13 years increased from 15% to 23.6% in girls and from 15% to 28.8% in boys, while the prevalence of obesity doubled for both sexes (Tremblay & Willms, 2000). In a Saskatchewan study the overall prevalence of
overweight children aged 8-12 was found to be 25.5%, with 27.3% of the girls defined as overweight and 23.3% of boys; while the occurrence of obesity was 7.1% in both sexes (Dupuis, 2007).

2.3 Childhood Obesity – Cause for Concern

Concern over the incidence of obesity in children exists for three main reasons: childhood health, effects on adult health, and health care costs. The major cause of concern pertains to health. The health risks related to obesity during childhood and adolescence have been well established (Must & Strauss, 1999). In general, being overweight or obese adversely affects overall quality of life. Schwimmer and colleagues (2003) demonstrated that severely obese children and adolescents had a lower health related quality of life (QOL) than children and adolescents who were of normal weight, and similar QOL to those children and adolescents diagnosed with cancer. Being obese increases a child’s risk of suffering from numerous health problems including: hypertension, hypercholesterolemia, heart disease, diabetes, decreased release of growth hormone, respiratory disorders, hepatic, renal, and orthopedic problems, as well as psychological and social complications (Styne, 2001; Anderson, 2000; Bar-Or et al., 1998). Overweight and obese children are also more likely to have poor self-esteem and an undesirable body image (Corbin, Corbin, Pangrazi, Petersen, & Pangrazi, 1997). If an obese child remains obese into adolescence and adulthood, his or her risk of the above mentioned health problems continues to increase and expands to include certain types of cancers (Styne, 2001; Anderson, 2000; Bar-Or et al., 1998). With the added health risks and complications due to obesity came the recognized risks of morbidity and mortality. In Canada the annual number of deaths attributable to overweight and obesity increased
from 2,514 in 1985 to 4,321 in 2000 (Katzmarzyk & Ardern, 2004). Overweight and obesity are important public health problems in Canada, accounting for approximately 57,000 deaths over the last 15 years (Katzmarzyk & Ardern, 2004); these authors concluded that immediate public health campaigns and interventions are required to slow or reverse the recent trends.

A second cause for concern regarding childhood obesity is that it may track into adulthood; that is, obese children are generally more likely to become obese adolescents and adults (Anderson, 2000). Evidence in the literature suggests that 70-80% of obese youth become obese adults (Bar-Or et al., 1998; Guo, Roche, Chumlea, Gardner & Siervogel, 1994) meaning that risks pertaining to health continue to be present and are likely to increase in adulthood. A BMI of 23 kg/m² at 18 years of age has been associated with an increased risk for obesity-related disorders. Individuals with a BMI greater than 25 kg/m² in adulthood are considered to be overweight; however, a BMI of 23 kg/m² has been found to be associated with negative health consequences related to excess fat mass. For boys with a BMI > 16 kg/m² at 4 years of age, 30.8% reached a BMI > 23 kg/m² at 18 years of age. However, for boys with a BMI > 19 kg/m² at 4 years of age, almost three times as many (89.5%) reached a BMI > 23 kg/m² at 18 years of age (He & Karlberg, 2002). This suggests that a child with a high BMI at 4 years of age is almost three times more likely to reach the BMI threshold associated with increased health risks by the end of the second decade of life.

The third reason for concern regarding childhood obesity pertains to economics. In the United States obesity carries an estimated annual national cost of $30 billion dollars (Donnelly, Jacobson, Whatley, Hill, Swift, Cherrington, et al., 1996), or an
estimated 10% of the American health care budget (Koplan & Dietz, 1999). Specifically
related to pediatric obesity, annual hospital costs are estimated to be $127 million
(Ebbeling, Pawlak, Ludwig, 2002). In Canada, the estimated annual cost in 2001 related
to excess fat mass was $4.3 billion dollars (Katzmarzyk & Jansen, 2004), though the
percentage of this attributable to childhood fat mass is currently unknown. If the current
trend of increasing obesity in society persists, then the associated costs and risks will
continue to escalate. The obvious solution to avoiding this unnecessary burden on health
and healthcare costs lies in prevention and a reversal of current trends.

In Canada and worldwide, rising rates of obesity over the past 20 years have
significant public health implications. According to the World Health Organization
(WHO) the impact of the obesity epidemic on non-communicable diseases such as
cardiovascular disease, Type 2 diabetes, and cancer threatens to overwhelm health
systems. Addressing obesity; however, requires knowledge of its determinants and root
causes.

2.4 Fat Composition

Body composition refers to the different components or compartments that make
up the human body; different individuals have varying proportions of these elements. Fat
mass is one of two, three, or four compartments generally considered to constitute body
composition (Plowman & Smith, 1997). In a two compartment model the compartments
are fat and fat-free mass, while a three compartment model breaks the fat-free component
into lean mass and bone mass. The four compartment model contains the inclusion of
water as a separate compartment. Fat is an important component of body composition
and, it must be noted that, humans cannot survive without it. Fat mass, which comprises
an average of 10-15% and 20-25% of young males and females body composition respectively, is also known as adipose tissue and these terms are often used interchangeably (Plowman & Smith, 1997). This is because adipose cells or adipocytes contain the majority of fat in the human body. Fat or lipids are also found in blood, bone marrow and interstitial fat cells. For the purpose of this thesis the discussion on fat will focus on adipose tissue. The traditional view of the adipose cell was one in which the cell provided a storage structure for fatty acids in the form of triacylglycerol molecules and supported the release of fatty acids when metabolic fuel was needed. Fat cells are responsible for these critical functions; however, the adipose cell is now better appreciated as a more complex organ.

Fat cells are distributed throughout the body in various organs and tissues, but they are largely clustered anatomically in structures known as fat depots. A fat depot includes a large number of adipocytes held together by a scaffold-like structure of collagen and other molecules. Fat depots are characterized by abundant neural connections and a rich network of blood vessels. Adipose cells are involved in many functions such as: the regulation of energy balance, responding to the energy demands of exercise, glucose and insulin metabolism, and lipid metabolism. Fat cells are also involved in a number of endocrine, autocrine, and paracrine actions. Thus, adipose cells not only play key roles in the flow of metabolic fuels, but are also involved in the regulation of several biological functions.

There are two distinct types of fat in the human body, termed brown and white fat because of their macroscopic appearance (Brook, 1978). Brown fat develops in advance of white adipose tissue and vacuoles fill with fat before birth (Brook, 1978). In contrast to
white fat, brown fat is only found in certain areas of the body, primarily around the kidneys, in the back of the neck, and in the interscapular region of the back in newborns. After infancy, brown adipose disappears in most areas of the body and accounts for less than 1% of the adipose tissue in adults (Stock & Rothwell, 1982).

White adipose tissue is comprised of fat cells, which generally contain a single, large droplet of lipid, primarily in the form of triglycerides. White adipose tissue is relatively well innervated and highly vascularized and is distributed throughout the body (Brook, 1978). Generally, a moderate proportion of the total adipose tissue is found internally around the viscera, kidneys, liver and other organs and the largest portion is distributed more superficially as subcutaneous fat. White fat is the major store of metabolic fuel and provides mechanical insulation and protection.

2.5 Changes in Fat due to Normal Growth and Development

Body composition can vary significantly within an individual during the transition from childhood into adulthood. During postnatal life, white adipose tissue expands because of interactive changes in the size of adipocytes and cellularity of the adipose tissue. Increases in adipocyte size (hypertrophy) and number (hyperplasia) are needed to accommodate the energy storage needs of the growing body. At birth the number of adipocytes within an average individual is approximately 5 billion. By adulthood the average number of adipocytes increases approximately six-fold, to 30-50 billion (Cheek, 1968). The average diameter of adipocytes also increases from about 30-40 µm at birth to about 80-100 µm in the young adult (Malina, Bouchard & Bar-Or, 2004). This does not mean that every individual will have a relatively higher fat mass in adulthood than infancy. Adipose cells can vary substantially in size and an increased number does not
always indicate increased fat mass. The increase in adipocyte number; however, does indicate that substantial changes occur within the body between infancy and adulthood (Knittle, Timmers, Ginsberg-Fellner, Brown, & Katz, 1979).

The average size of adipocytes has been reported to increase twofold to threefold during the first year of life, reflecting the rapid filling of existing adipocytes at which point a nadir, a temporal low point, is reached. Subsequently, the mean size of the adipocytes does not increase significantly in normal weight children until the on-set of puberty. Prior to puberty no sex differences occur; however, a small increase in the average size of fat cells is more obvious in girls than boys at puberty. Variability in average fat cell size is generally stable during childhood, but increases with age through adolescence. The cellularity of adipose tissue (number of cells) does not increase significantly early in life suggesting that the gain in fat mass early in life is the result of an increase in the size of existing adipocytes. However, from about one or two years of age and continuing through childhood, the number of fat cells increases gradually. The cellularity of adipocytes then almost doubles at the onset of puberty and is followed by a plateau in late adolescence and early adulthood. The adipocyte number is almost identical in both sexes throughout childhood, but girls experience a greater increase than boys at puberty.

Fat composition and, in particular, percent body fat can be measured in several ways. Skinfolds are the easiest and most common method of estimating percent body fat. A set of calipers is used to measure the thickness of subcutaneous fat, the fat right beneath the skin, in multiple places on the body. It should be noted that skin thickness will also be included in the measure. These values can then be entered into validated
regression equations to estimate total body percent fat. Different sites on the body are measured to determine the distribution (central versus extremity fat) as well as percent body fat. Using skinfolds as an estimate of subcutaneous fat mass, Tanner (1978) reported that after peaking at around 9 months after birth, subcutaneous fat mass (SFM) decreases gradually until 5-8 years of age, at which point it begins to increase again. Along with SFM, mean BMI levels increase rapidly during the first year of life, but then decrease and reach a nadir at 4-8 years of age. Subsequent to this nadir; SFM and BMI increase and in healthy individuals BMI reaches values of 20-25 kg/m^2 by adulthood (Tanner, 1978) (Figure 2.1).

Figure 2.1 – Growth Curve BMI

BMI curve adapted from Centers for Disease Control and prevention (CDC) growth charts (2002). The 50th centile line represents the average BMI of the population.

This increase is significantly different between the sexes. Girls experience a linear increase in both trunk and limb subcutaneous fat from 6-7 yrs of age through puberty;
whereas, boys experience a slight increase between 6-7 yrs to 12-13 yrs followed by a decrease during puberty; however, males do accumulate proportionally more visceral fat adipose (deep, internal adipose) than females during puberty. Thus, a sex difference in the distribution of body fat occurs during puberty resulting in the apple and pear shape seen in most adult males and females, respectively.

2.6 Critical Periods of Fat Deposition

Three critical time periods have been identified for the development of fat mass: fetal life, the period of adiposity rebound between ages 4 and 6 (the beginning of the post-infancy rise in BMI) and finally, adolescence. A critical period refers to a developmental stage in which physiologic alterations increase the risk for later obesity (Dietz, 1997).

2.6.1 Fetal Life

Some of the earliest data relating to the development of obesity and fetal life is from the Dutch famine study (Dietz, 1997). This study was a natural experiment reporting events that occurred near the end of World War II (1944-1945). Food rations declined in northern Holland over a six month period from ~1500 kcal to ~500 kcal per person per day. It was found that individuals who were exposed to famine during the last trimester of their fetal growth were found to have a reduced prevalence of obesity at age 18; interestingly an increased prevalence of obesity was observed among individuals exposed to famine in the first two trimesters (Dietz, 1997). However, the lack of birth weight measurements suggest that birth weight may have confounded these associations because low birth weight is more likely with late intrauterine exposure to under nutrition (Dietz, 1997). The last trimester of fetal life represents a period of adipocyte replication
and rapid increase in body fat (Strass & Dietz, 1997); this suggests that reduced fetal fat
deposition late in pregnancy may lead to subsequent leanness in adulthood. Interest in
these observations was heightened by the observation that low-birth weight infants
appeared to be at increased risk of hypertension, hyperlipidemia, and glucose intolerance
in adulthood and by the suggestion that abnormalities were mediated by abdominal fat
deposition (Dietz & Gortmaker, 2001).

Other investigations have found positive relationships between high birth weight
and increased adult adiposity. For example Seidman and colleagues (1991) found that 17
year old youth with birth weights greater than 4500 grams, when compared to 17 year old
youth with birth weights between 3000 – 3499 grams, were four times more likely to be
obese. Infants who are exposed to gestational diabetes also have higher births weights
and are more likely to be overweight or obese at all ages throughout childhood and
adolescence (Pettit, Baird, Aleck, Bennett, & Knowler, 1983; Whitaker, Pepe, Seidel,
Wright, & Knopp, 1996). In addition, increased birth weight resulting from gestational
diabetes, appears to be consistently associated with increased BMI in adulthood (Curhan,
Chertow, Willett, Spiegelman, Colditz, Rimm, et al., 1996). A number of potential
mechanisms could account for the effect of prenatal growth on subsequent adiposity;
however, the processes that promote total and regional inuterine fat disposition are still
relatively unknown (Dietz, 1997). Therefore, a paradox arises, where normal birth
weight children do not appear to be at an increased risk for the development of obesity in
young adulthood, both low birth weight children and high birth weight children appear to
be at an increased risk.
2.6.2 Adiposity Rebound

After an initial increase in the first year of life, BMI and relative adiposity declines and reaches a nadir between 4 and 8 years of age. The subsequent increase, after the nadir, in BMI and adiposity has been termed the adiposity rebound (AR) (Freedman, Khan, Serdula, Srinivasan, & Berenson, 2001; Taylor, et al., 2004). As with a number of growth parameters AR can only be identified if serial measures are taken. The timing of the AR is important for predicting overweight and obesity in adulthood (He & Karlberg, 2002). Dorosty and colleagues (2000) found that an early AR was associated with a higher BMI in adolescence and early adulthood as well as a substantial increase in the risk of adult obesity. They also found that having at least one obese parent increased the risk of an earlier AR. A recent article by Taylor et al. (2004) reported that girls who underwent an earlier AR (age <5 yrs) had a faster and more significant rate of fat gain than girls who were classified as having a later AR (age >5 yrs). They observed that although body composition was similar at age 5, by age 9 girls with an early AR had a significantly greater percent body fat (29%) when compared to girls with a later AR (11%). Freedman et al. (2001) found that girls who had an AR at 7 years of age or later had a lower BMI at age 5 than girls who had an earlier rebound. They also found that individuals who were taller at 5 years of age generally had an earlier AR and were more likely to become obese adults. An increased BMI at age four has been found to result in an increased BMI in early adulthood and an increased risk for obesity related conditions (He & Karlberg, 2002); however, the mechanics by which AR influences adult obesity remain unclear. It has been suggested that an early AR may reflect exposure to
gestational diabetes, be a marker for generalized growth acceleration, or provide a longer period during which adipose tissue can accumulate (Freedman, et al., 2001).

2.6.3 Adolescence

The final critical period for fat mass development is adolescence. Childhood obesity has the greatest likelihood of tracking into adulthood if the individual is also overweight as an adolescent (Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). Adolescence represents a period of increased risk of obesity in girls, but it is also the period in which the location of body fat changes, and thus may entrain the subsequent risks associated with obesity in males as well (Dietz, 1997). Using longitudinal data from the UK Braddon, Rogers, Wadsworth, and Davies (1986) examined the prevalence of early obesity among 36 year old men and women. The researchers found that in men, about 10% of adult obesity began in early adolescence; that is, these individuals were already obese in adolescence, whereas in females that proportion was 30%. Among girls, more so than boys, earlier onset of puberty and menarche are associated with higher levels of fatness and higher risk for overweight and obesity. In girls, body fat changes from approximately 17% of body mass to 24% of body mass over the period of adolescence, although significant individual variation occurs (Dietz, 1997). Boys ordinarily decline in relative fatness (% fat) during puberty; however, the absolute amount of fat mass increases from childhood through adolescence. Central deposition of body fat is associated with an increased risk of cardiovascular related illness. Examining intra-abdominal adipose tissue in 16 healthy children, Goran and colleague (1995) found that the central deposition of body fat increased fivefold in boys during adolescence, whereas this increase in girls was only approximately threefold. Like girls, early
maturing boys tend to have, on average, a higher BMI during childhood, which persists through adolescence. Overweight adolescent males have an increased early mortality in adulthood and both overweight adolescent males and females have an increased adult morbidity, which appears independent of the effects of adolescent weight on adult weight (Must, Jacques, Dallal, Bajema, & Dietz, 1992).

2.7 Childhood Physical Activity and Fat Mass Development

The remarkable rate of change in the prevalence of obesity over the past 30 years suggests that lifestyle rather than genetic factors may be primarily responsible for the rapid increase in childhood obesity rates (Moore, Gao, Bardlee, Cupples, Sundrarajan-Ramautri, Proctor, Hood et al., 2003). Overweight and obesity are generally caused by a positive energy balance – more calories are consumed than expended. These conditions are influenced by either high energy intake, low energy expenditure, or a combination of the two. A significant body of research suggests that body composition (fat and bone tissue) is affected by physical activity (Bar-Or & Baranowski, 1994; Garaulet, et al, 2000; Maffeis, et al., 1996). However, data dealing with the effects of physical activity and specifically sport training on fat mass distribution during growth is lacking (Malina, Bouchard, & Bar-Or, 2004).

There is some evidence from cross-sectional and longitudinal observational studies that youth of both sexes who participate in relatively high levels of physical activity have less adiposity than less active youth. (Berkey, Rockett, Field, Gillman, Frazier, Camargo, et al., 2000; Rowlands, Eston, Ingledew, 1997; Lazzer, Boirie, Bitar, Montauier, Vernet, Meyer, et al., 2000). Berkey and colleagues (2000) examined the role of physical activity, inactivity, and dietary patterns on annual weight changes among
preadolescents and adolescents while accounting for normal growth and maturation. A cohort of 6,149 girls and 4,620 boys between the ages of 9-14 years completed a questionnaire in 1996 and, again, a year later in 1997 providing detailed information on their current height, weight, and physical activities, among other variables. They found that for both boys and girls, a one-year increase in BMI was greater in those who reported spending more time in sedentary activities, such as TV and video watching, and less time engaged in physical activities (Berkey, et al., 2000). Larger year-to-year increases in BMI were also observed in girls who reported higher calorie intakes and less physical activity between the two BMI measurements. The authors reported that although the magnitudes of the effects were small, their cumulative effects during adolescence would produce substantial weight gains (Berkey et al., 2000). Although this study had a large sample size, it must be noted that these measures were self-reported thus adding limitation to the findings; since self-reported height and weight as well as physical activity scores are less accurate then more precise measures of these variables (Cale, 1998; Kalasson-Heggebo & Anderssen, 2003).

To observe the relationships between physical activity, physical inactivity, and weight in American adolescents, Eisenmann and colleagues (2002) examined data from a nationally representative sample of 15,143 American high school students 14-18 years of age participating in the 1999 Center for Disease Control (CDC) Youth Risk Behavior Survey. Prevalence rates of participation in moderate physical activity (MPA), vigorous physical activity (VPA), and television watching were determined (Eisenmann, Bartee & Wang, 2002). Activity groups were established based on the number of bouts of exercise per week, six-seven bouts per week, three to five, and less than two. BMI was derived
from self reported height and weight; overweight was defined using the age and sex
specific ≥ 85th percentiles of BMI from the CDC growth charts. Boys reporting six to
seven bouts of MPA had a significantly lower BMI compared with boys reporting three
to five or less than two bouts of MPA. The mean BMI differed significantly between the
lowest and highest levels of MPA in girls, with girls participating in the highest levels of
MPA having the lowest BMI. The mean BMI was also significantly lower in the highest
VPA group compared with the other two groups in both sexes (Eisenmann et al., 2002).
This finding suggests that boys and girls who participate in moderate to vigorous activity
at least three times per week have a lower BMI and are less likely to be overweight
compared to adolescents who do not. Adolescents were also found to be 20-25% less
likely to be classified as overweight if they reported watching 2-3 hour of TV per day and
were 40% less likely to be classified as overweight if they reported watching less than
one hour per day compared with those youth who reported watching more than four hours
of TV per day. The prevalence of obesity increased 2% with every additional hour of TV
per day. In general, adolescents who engaged in less physical activity watched more TV
per week. The authors found that the relationship between time spent watching TV and
weight status was more pronounced than the relationship between time spent engaged in
MPA and VPA and weight (Eisenmann et al., 2002). However, in this study indirect
measures were used to determine physical activity and a self report measure was used for
BMI. Thus there may be an underestimation of prevalence of overweight and obesity
because height is often overestimated and weight underestimated in self-report (Epstein,
Valoski, Kalarchain, & McCurley, 1995).
The benefits of physical activity on fat mass accumulation have been demonstrated in younger children as well. Reilly and colleagues (2005) longitudinally examined the early life risk factors for obesity in childhood. They found that parental obesity, early AR, more than 8 h/wk TV viewing at age 3, catch up growth, weight gain in the first year of life, birth weight, and lack of sleep to be associated with a risk for obesity. Reilly et al. (2005) concluded that early life environment is an important factor in determining the risk of obesity later in life. Vogels and colleagues (2006) investigated the effects of early development and behavioral determinants on overweight at 12 years of age. Subjects (n=105) were recruited from a Dutch cohort of children born between 1990 and 1993 and anthropometric measures were conducted annually from birth until 7 years of age and, again, at age 12. The authors reported that from the first year of life BMI tracked significantly with BMI at age 12 and that overweight at 12 years of age was predicted by an early rapid increase in body weight. They also observed that percentage body fat was negatively associated with the child’s physical activity score (Vogels, Pasthumus, Mariman, Bouwman, Kester, Rump, et al., 2006). However, it is necessary to note that physical activity was assessed using an indirect method, the Baecke questionnaire, which is less accurate than a direct measure of physical activity such as accelerometers.

Janz et al. (2002) examined cross-sectional associations among fatness, leanness, and physical activity in 467 children aged 4-6 years residing in Iowa. Activity was measured using an accelerometer and inactivity was assessed using a parental proxy report of children’s TV viewing. Dual energy X-ray absorptiometry was used to measure body composition (fat and lean tissue mass). The authors concluded that 4 to 6 years of
age was a critical period for preventing adult obesity because the age at which body
fatness reaches a post-infancy low is inversely associated with obesity later in life (Janz,
Levy, Burns, Torner, Willing & Warren, 2002). Minutes spent in vigorous activity and
TV viewing were the variables most consistently and most highly associated with
adiposity. They also found total physical activity to be inversely related with all adiposity
variables. Physical activity was associated with decreased fatness and increased
leanness, while hours of TV viewing was associated with increased fatness and decreased
leanness. The most active children who spent the least amount of time watching TV had
6.8% (boys) and 4.4% (girls) less fat mass than children, who were least active and spent
the most time watching TV. Total physical activity was also associated with increased
fat free mass in girls. Janz et al. (2002) found low levels of physical activity to be
associated with increased fatness during the period of adiposity rebound.

Moore et al. (2003) monitored 103 American children longitudinally beginning in
early childhood (3-5 years of age). Physical activity was assessed for eight years using
accelerometer motion sensors for 3-5 consecutive days; body composition was also
assessed annually using skinfold calipers to determine adiposity and to calculate percent
body fat. The authors found that children engaged in the highest levels of daily activity
had consistently smaller gains in BMI, and in triceps and sum of five skinfolds
thicknesses throughout childhood. The protective effect of activity was evident for both
boys and girls. They concluded that higher levels of physical activity during early
childhood (3-5 years) lead to the acquisition of less body fat by the time of early
adolescence (Moore, et al., 2003).
Goran et al. (1997) examined whether body fat content in pre-pubertal children was influenced by physical activity related energy expenditure, time and intensity, and/or more qualitative aspects of physical activity: type and duration. One hundred and one prepubertal children (age 5.3 ± 0.9 yrs) were examined. Body composition was assessed through the use of skinfolds and bioelectrical impedance, total energy expenditure by doubly labeled water and physical activity through the use of a questionnaire. Goran and colleagues found that activity energy expenditure was highly variable and only weakly related to fat free mass and body weight. In addition the daily energy cost of physical activity was unrelated to time spent performing physical activities; they demonstrated that fat mass was more related to activity time than to the combined energy cost of physical activities (Goran, et al., 1997). These results suggest that time devoted to recreational physical activity may be a more important factor in the maintenance of whole body energy stores than the combined daily energy cost of physical activity. Therefore, long bouts of physical activity, which can be a lower intensity, may be more protective than shorter bouts of high intensity activity; this may be a result of less time spent in sedentary activities. These finding suggest that modifying physical activity levels in early childhood may be more beneficial than modifying them later in childhood and adolescence. Establishing a healthy lifestyle in early childhood may lead to better retention of that lifestyle than initiation later in life. However, the duration and frequency as well as the mode of exercise most beneficial for decreasing fat mass in the pediatric population and delaying the onset of the adiposity rebound are still a matter of debate.
2.8 Gymnastics Training and Fat Mass

Vigorous physical activity has been suggested as one of the most effective means of affecting fat mass accrual in children (Barbeau & Litaker, 2003). Although gymnastics is a sport involving short bouts of physical activity, young children are exposed to relatively high physical demands. Little research has been conducted on the effects of gymnastics training on fat mass development; however, elite gymnasts have been consistently portrayed as being lighter and having a decreased fat mass compared to other sporting groups and reference populations.

Laing and colleagues (2002) conducted a prospective study of bone mass and body composition in seven adolescent (aged 11.7 ± 2.4 years) female artistic gymnasts. Body composition was assessed using dual energy X-ray absorptiometry. At baseline they found that the gymnasts, who had, on average, been training for 5.9 years, had significantly less fat mass and a lower percent body fat than the age, height, and weight matched non-gymnast controls. They also found that during the three years of follow-up fat mass and percent fat did not change between the groups, indicating that gymnasts maintained their lower absolute fat mass and percent body fat regardless of training status. Gurd and Klentrou (2003) found similar results when studying the effects of gymnastics training in 21 adolescent (aged 13.3 ± 0.3 years) male gymnasts. Male gymnasts had to be competing at a minimum of a provincial level and had been training at least 15 hours per week. The controls were recruited from recreational martial arts classes to create a physically active comparison group; however, these boys did not train more than two hours per week. Relative body fat was measured by bioelectrical impedance. Gurd and Klentrou (2003) found that the male gymnasts had significantly
lower relative body fat (% body fat), despite no significant difference in body weight compared to age-matched active controls. This would suggest that the gymnastics training resulted in decreased fat mass and increased lean mass compared to active controls.

Weimann (2002) examined gender related differences in elite gymnasts. Twenty-two female (aged 13.6 ± 1.0 y) and 18 male (aged 12.4 ± 1.6 y) elite national gymnasts training at the Olympic training center in Frankfurt Germany were recruited. Skinfold thickness and bioelectrical impedance were used as indirect methods for determining body composition and to evaluate changes in fat mass and fat free mass. As expected, the percentage fat mass was, on average, significantly greater in females than males. Both male and female gymnasts were found to have a percent body fat that was lower than reference population norms. With increased duration of training, the percentage of body fat was reduced to a greater extent in female gymnasts compared to their male counterparts. However, in the female gymnasts, the mean percentage of fat mass increased from 12.3%-15.3% during the pubertal development, while the male gymnasts showed a decrease in relative fat mass. This is congruent with the normal pattern of fat mass development seen during puberty.

Similar results have been found when looking at younger age groups. This is important as it has been suggested that training programs may be more effective if they are initiated early in life, perhaps during the preschool years. Filaire and Lac (2002) studied the nutritional status and body composition of 12 juvenile (aged 10.1 ± 0.3 years) elite female gymnasts. The gymnasts had been involved in the sport for at least five years and trained four-five days a week for four hours per day in addition to their usual school
activities. A group of girls not actively engaged in sport, except during school hours, were recruited from a primary school to serve as controls. All gymnasts and controls were prepubertal at the time of testing. Skinfold thickness was measured to estimate percent body fat and dietary data were assessed using a 7-day consecutive food record. The authors found that although the mean dietary intake was higher in gymnasts the gymnasts exhibited a significantly lower percentage body fat. This finding indicates that the gymnastics training rather a dietary restriction was resulting in the decreased fat mass observed in these young gymnasts.

Zanker et al. (2003) observed 20 children 7-8 years of age who were participating in artistic gymnastics and compared them to 20 sex, age, height, and weight-matched controls. The gymnasts included 10 females and 10 males. The female gymnasts trained 8-10 hours per week and had been training regularly for 3-4 years. The male gymnasts trained 4-6 hours per week and had been involved in systematic training for 1-2 years. Dual energy X-ray absorptiometry was used to assess fat mass and percent body fat. Gymnasts displayed a significantly lower fat mass than untrained children of the same sex: a 45% and 43% difference for male and female gymnasts, respectively.

The majority of evidence indicates a protective effect of physical activity on fat mass development in children and adolescents. It has been suggested that early childhood (4-6 years) is a critical period for the development of fat mass and thus an important age for physical activity interventions. High levels of physical activity in early childhood have been associated with decreased fatness and it has been suggested that initiatives begun in early childhood are more likely to be maintained in adolescence and adulthood. Gymnasts, measured in late childhood and early adolescence, have been consistently
found to have less fat mass and a decreased percent body fat. However, the effects of gymnastics training in early childhood, which has been identified as a critical period, are relatively unknown.

2.9 Osteoporosis

Osteoporosis is the most common bone disorder in the world, affecting 30% of all post-menopausal women (World Health Organization). In the United States, more than 10 million individuals have osteoporosis and more than 34 million have osteopenia, which refers to low bone mass (Rizer, 2006). Osteoporosis is a major cause of loss of independence in the elderly with approximately 60% of women and 30% of men over the age of 50 suffering from an osteoporotic fracture in their remaining lifetimes (US Department of Health and Human Services, 2004). Osteoporosis is defined as a disease process characterized by low bone mass and micro architectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk (The Consensus on Development Conference, 1993). Osteoporosis has serious physical, psychological, and financial consequences, placing a significant burden on individuals, the families of those affected, and society. Fractures related to osteoporosis often entail a number of serious complications, which in turn lead to enormous expense and often death (Lorrain, Paiement, Chevrier, Lalumiere, Caron & Fillion, 2003). The total direct medical costs for this disease are estimated to be $1.3 billion per year in Canada and are expected to continue to increase (Lorrain et al., 2003).

A marked increase in the annual incidence of osteoporotic fractures in Canada has been noted by many researchers. The frequency of hip fractures, for example, was less than 20,000 in 1981 compared to 27,342 in 1995, with 73% occurring in women (Lorrain
et al., 2003). For Canadian women the risk of hip fractures over their remaining lifetime is estimated to be 17.4%, a risk that is greater than the risk for life of breast cancer (Papadimitropoulos, Coyte, Josse, and Greenwood, 1997). The annual economic implications of hip fracture in Canada was $650 million and is expected to rise to $2.4 billion by 2041 (Wiktorowicz, Goeree, Papaioannou, Acdachi and Papadimitropoulos, 2001).

The burden of osteoporosis has largely been assessed in terms of fracture incident rates and economic costs; however, the physical, psychological and social consequences of osteoporotic fractures must also be considered when quantifying the impact of this disease. For example, it is estimated that only one half of individuals who suffer an osteoporotic hip fracture will ever regain normal life activities (Lorrain et al., 2003). Individuals with these fractures often have a reduced ability to perform daily household and self-care activities such as cooking, vacuuming, bathing and dressing (Huang, Ross, and Wasnich, 1996). Adachi and colleagues (2001) found that health-related quality of life deceased in women and men following an osteoporotic fracture and that this health-related quality of life impairment was long term. In a survey of women aged 75 years and over 80% of the women surveyed said they would rather be dead than experience the loss of independence and quality of life that results from a hip fracture (Salkeld, Cameron, Cumming, Easter, Seymore, Kurrle & Quinn, 2000). Unless decisive steps for preventive intervention are taken now, a catastrophic global epidemic of osteoporosis seems inevitable (Riggs and Melton, 1995).

Osteoporosis is an age-related metabolic bone disorder characterized by low bone density and structural deterioration of bone tissue; as such it is imperative to maximize
the attainment of peak bone mass and delay the onset of bone loss. Obtaining and maintaining high levels of bone mineral density is the single best defense against osteoporosis. A 10% increase in adult bone mineral content at the femoral neck reduces the risk of fracture at that site by one half (Cumming et al., 1993). Adolescence is the single most opportune time to modify the mass and geometry of the skeleton (Proctor et al., 2002); therefore, the amount of bone gained during childhood and adolescence has a significant impact on lifetime skeletal health. Although the genetic contribution to variability in bone mass has been estimated to be as high as 80%, evidence continues to accumulate suggesting that modifiable factors, such as physical activity, diet, and menstrual status, can influence bone mass (Kirchner, Lewis, & O’Conner, 1995).

2.10 Bone Composition

The human skeleton is made up of 206 individual bones. On the macroscopic level the skeleton can be divided into two parts, the axial and appendicular skeleton. The axial skeleton includes: the vertebrae, the pelvis, the skull, and other flat bones such as the scapula. The appendicular skeleton includes all the long bones. The skeleton’s function is to serve as a framework for the body, protect vital organs, and facilitate movement by acting as a sequence of levers. Skeletal bone also plays a role in body processes such as immune function and calcium and phosphate homeostasis. Bone is a remarkable structure comprised of a strength greater than oak, brick, or even concrete (Einhorn, 1996), a bending resistance as effective as cast iron yet weighing only one-third as much per unit of volume, and a flexibility that allows for absorption of sudden impacts without fracture (Forwood, & Burr, 1993).
There are two types of bone tissue, cortical bone and trabecular bone. The skeleton is comprised of approximately 75-80% cortical bone and 20-25% trabecular bone. An important difference between cortical and trabecular bone is in the way the bone matrix and cellular elements are arranged. These differences permit the two types of bone to function differently (Khan, McKay, Kannus, Bailey, Wark, & Bennell, 2001). Cortical or compact bone is a densely compacted tissue that forms the outer surface of all bones and is primarily found in the appendicular skeleton. It provides structure and ensures the integrity of the skeleton. The trabecular or cancellous bone is a spongy lattice-like structure made of horizontal and vertical interconnecting plates called trabeculae. The trabeculae are situated inside the cortical bone shell, in some of the flat bone, the vertebral bodies, and the metaphyses of long bone. The trabecular bone is architecturally adapted to withstand mechanical stress and is more responsive to the metabolic demands of the skeleton because of its higher surface area to volume ratio. This arrangement permits bone marrow, blood vessels, and connective tissue to be in contact with the endosteum bone which has an active metabolic role (Khan, et al., 2001). In living human bone the amount of strength due to the architectural structure cannot be measured directly, thus bone strength is often estimated by a measurement of the bone’s mineral content and mineral density.

2.11 Changes in Bone due to Normal Growth and Maturation

Growth is the attainment of size of a given tissue by an increase in number of cells (hyperplasia), size of cells (hypertrophy), or an increase in cellular matrix. It is the expression of the genetic program and is under the control of the endocrine system (Ohlsson, Isgaard, Tornell, Nilsson, Isaksson and Lindahl, 1993). The growth of the
skeleton determines the size and proportion of the body. This process is tightly regulated. In the case of bone growth, it is the process of enlargement of the skeleton and it occurs in two ways. The first is longitudinal growth or growth in length. This occurs as a function of a cycle of activities in the cartilaginous growth plates. The growth plate (physes disc) is a narrow band made up of two zones; the proliferating cartilage zone and the cartilage hypertrophy zone. Multiplication of cartilage cells and elaboration of intercellular matrix occur in the zone of cartilage proliferation. In the proceeding zone, cartilage cells are arranged into columns and then swell and calcify. Ossification of these cells then occurs in the metaphys. This process takes place at both epiphyseal physes (between the ends of long bones and their shafts) and apophyseals (between condyles, trocanter, shaft, etc.) and it produces cancellous bone (Parfitt, 1994).

The second type of bone growth is circumferential growth or growth in width. The diameter of a bone enlarges through appositional growth at the outer (periosteal) surface. Bone is deposited on the periosteal surface and resorbed on the inner (endosteal) surface producing cortical bone (Parfitt, 1994). As a result the marrow cavity gradually enlarges as the bone increases in diameter. Whereas physes discs usually fuse between 18-25 years of age and longitudinal growth ceases, circumferential growth occurs throughout life.

In addition to growing in length and width, the bone must also be modeled and remodeled to maintain its shape. Bone remodeling and repair may involve a change in the shape or internal architecture of a bone or a change in the total amount of minerals deposited in the skeleton. This is achieved though a constant process of bone deposition and bone resorption. In growing individuals, bone deposition occurs at a more rapid rate
than bone resorption. In young and middle-aged adults, rates are ordinarily in
equilibrium, whereas, in older adults, bone resorption occurs at a more rapid rate than
bone deposition.

Bone mineral content (BMC) increases linearly with age with no gender
difference in childhood. Girls appear to have slightly greater BMC in early adolescence,
which is likely a reflection of earlier timing of the female growth spurt (12 years of age).
Boys have their growth spurt later (14 years of age) than girls and continue to increase in
BMC through late adolescence when girls have ceased. Bone mineral density (BMD)
follows a similar pattern of accrual as BMC. Bone mineralization increases progressively
in early childhood and then accelerates in adolescence. Bailey (1997) reported that at the
age of peak height velocity both boys and girls have attained approximately 90% of adult
stature, 70% of adult BMC at the femoral neck (hip), and approximately 60% at the
lumbar spine and total body. In the four years surrounding peak height velocity, 35% of
total body and lumbar spine, and 27% of femoral neck BMC is accrued (Bailey, 1997).

2.12 Bone Adaptation

A bone will adapt to the load applied in order to maintain efficiency in providing
structural and functional support to the skeleton without injury or fracture. The adaptation
of the bone to loading will be to increase its size, change geometry and increase the
amount of mass within the periosteal envelope (Ward, 2005). When a mechanical load is
placed on a bone it causes a slight deformation or “strain” which is resisted by
intermolecular bonds “stress”. For a given bone structure, the loads to which it is
subjected will determine the strain. An increased load, such as the increased use of the
lower limbs in gymnastics landings, will increase the strain on the bone. It is thought that
there are two main processes by which bone adapts to mechanical load and increased strain: modeling and remodeling.

Modeling is an organized cell activity that allows bone to grow and adjusts bone strength through the addition and resorption of bone at separate anatomical sites. Bone modeling involves independent actions of osteoblasts and osteoclasts. Accretion occurs without prior resorption and results in a net gain of bone tissue. Bone modeling is most active in infants and tends to subside after skeletal maturity. It fits a growing bone’s architecture to the mechanical demands of physical activity, body weight, and neuromotor function (Frost, 1990).

Bone remodeling is also stimulated by mechanical loading; however, it is important to note that it is a different process than modeling. Bone remodeling differs in that osteoblasts and osteocasts do not act independently, but rather are coupled and bone resorption and formation occur at the same spot on a bone surface. The activity is locally coordinated (Khan, et al., 2001). Remodeling is a continuous process throughout life, which provides a mechanism whereby fatigue-damaged bone is replaced with new bone, ion homeostasis is maintained, and bone is reinforced for increased stress. At any given time, about 20% of the skeleton is undergoing remodeling (Parfitt, 1994). Every year the human body replaces 10% of its bone mass. In the aging and osteoporotic skeleton, however; the balance between the amount of bone resorbed and formed is shifted in favor of resorption and a net bone loss results. In women, bone loss usually begins at age 45 at an average rate of 1% per year until age 65, and it slightly decreases after that (Lorrain et al., 2003).
2.13 Childhood Physical Activity and Bone Health

There is growing evidence to support the assertion that bone mineral density increases as a result of high-impact aerobic and strength building or weight-bearing exercise at any age; however, the evidence also suggests that the capacity of bone to adapt its mass to such activity is greatest before puberty because of a higher rate of modeling and remodeling processes that promote adaptations in the size, shape, and mineralization of bone to accommodate loads (Bass, 2000). Two distinct skeletal processes occur during skeletal maturation: bone growth and bone modeling. During skeletal maturation, the modeling process must be optimized to maximize bone accretion. Physical activity must be maintained throughout childhood and during adolescence in order for the modeling process to increase bone deposits (Frost 1987, Prafitt, 1994). Appropriate mechanical loading during the critical period of rapid skeletal growth and modeling in children, therefore; would appear important for future skeletal health (Grimston, Willows and Hanley, 1993).

The growing skeleton has been shown to respond to increases in everyday physical activity by increased bone mineral accrual (Bailey, McKay, Mirwald, Crocker and Faulkner, 1999). In one of the first studies on the effects of physical activity on BMD, Slemenda and colleagues (1991) examined 59 pairs of monozygotic twins (n=118), 6-14 years of age at study entry, enrolled in a longitudinal study of calcium intake, supplementation, and bone growth. Bone mass in the radius was measured using single-photon absorptiometry and bone mass in the spine and hip were measured using dual-photon absorptiometry, while physical activity was assessed via a questionnaire. The authors found that although the activities reported by the boys and girls were
different, there were no differences in total hours spent participating in weight-bearing activities between the genders. Boys were found to have significantly greater BMD in the Ward’s Triangle (hip) and girls had significantly greater BMD in the lumbar spine. In normal children aged 5-14 years, total hours of weight bearing activity correlated significantly with bone density in the radius and upper femur. Non-weight bearing activities, such as swimming and biking, did not show positive associations with BMD and in some cases demonstrated a negative correlation. Slemenda et al. also found that children with physical activity levels one standard deviation above the mean (2.7 h/day) were likely to emerge from adolescence with 5-10% greater bone mass. The authors concluded that a moderate increase in the level of weight-bearing physical activity among children could be associated with a moderate, but important, increase in skeletal mass (Slemenda, Miller, Hui, Reister and Johnson, 1991). In a subsequent 3-year observational study of the same cohort, the authors found a 4-7% greater increase in femur BMD for prepubertal children in the highest, compared to lowest, quartile of physical activity (Slemenda, Resiter, Hui, Miller, Christian, & Johnson, 1994). These findings indicate that children involved in the greatest volume of normal everyday physical activity had greater bone mass than children who participated in less physical activity.

Evidence for the beneficial effect of everyday physical activity on bone mineral accrual was apparent in a six-year longitudinal study of Canadian children. Bailey et al. (1999) investigated the influence of physical activity on bone mineral accrual during the adolescent years; 60 boys and 53 girls with longitudinal data spanning the adolescent years were examined. BMC was measured using dual energy X-ray absorptiometry and
physical activity was assessed via a questionnaire. Physical activity groups (physically inactive, average activity, and physically active) were formed based on the score derived from the physical activity questionnaire. Bailey and colleagues reported that children in the highest quartile, the most physically active, accrued more bone during the 2 years around peak bone mineral accrual velocity and had greater BMC than those in the lowest quartile of physical activity 1 year after peak bone mineral accrual velocity. This resulted in as much as 17% greater total body, 18% greater lumbar spine, and 11% greater femoral neck BMC in active girls one year after peak BMC velocity. Slemenda and colleagues (1994) in the study described above also found that physical activity was associated with more rapid mineralization in prepubertal children and reported a 29% increase in bone mineral content at the lumbar spine in the 3 years around the onset of puberty.

Childhood activities that preferentially stress one side of the body over the other provide a unique model for studying the effects of mechanical loading on the growing skeleton (Bailey, Faulkner, & McKay, 1996). The non-dominant side of the body is used as a control for genetic, nutritional, and hormonal differences. Differences in bone mineralization can thus be attributed to the different loading patterns of the two limbs. This model of study addresses the criticism that individuals with greater BMC and BMD excel at sports and that it is predisposition rather than training that results in the observed increases in BMC and BMD. Haapasalo and colleagues (1994) examined 19 female Finnish national level squash players (aged 25.4 ± 4.0 years) and 19 health Finnish women (aged 25.4 ± 3.9 years). The squash players had been actively training for 5.7 ± 8.5 years, ranging from 2-12 years. They trained four times a week for approximately 75
minutes each session. BMC and BMD were measured at six different sites in the upper arm using dual energy X-ray absorptiometry. The squash players exhibited significantly higher BMC and BMD values in all measured sites of their dominant playing arm compared to their non-dominant arm. Controls also had greater BMC and BMD in their dominant arm. These perceptual side-to-side differences were significantly greater in the squash players than the controls. Significantly larger side-to-side differences (average 22%) were also found in players who started their training before or during menarche than those who started 1 or more years after the event (9%). Kannus et al. (1996) compared the BMC of 105 adult female national level tennis and squash players and 50 health female controls using dual energy X-ray absorptiometry. The tennis and squash players were divided into six groups according to their biological age when playing started. Compared to the control group, the tennis and squash players had significantly larger side-to-side differences in BMC. The authors also found that the players who started their career before or at menarche exhibited a difference 2-4 times higher than those who started after menarche. Kannus and colleagues recommended that physical activity should be started no later than puberty to be maximally effective for bone gain. The increased bone mineral density found in the dominant playing arm of racquet athletes from unilateral studies support the assertion that bone mineral density increases as a result of physical activity. The non-playing arm was used as a control for genetics, diet, hormonal, and other variables that have been suggested as alternative explanations to the increases in bone observed in athletes involved in impact-loading sports. These findings suggest that physical activity, and not genetics, was responsible for the increases in bone mineral density.
Strategies that increase the acquisition of bone mass during childhood may help protect skeletal integrity and reduce the risk of osteoporosis in later life (Zanker, Gannon, Cooke, Gee, Oldroyd & Truscott, 2003); however, the mode of physical activity as well as the intensity, duration, and frequency of exercise that is optimal or beneficial for accretion of bone mineral is not well established. Taaffe et al. (1995; 1997) suggested that high-magnitude mechanical loads are more osteotropic than low-intensity loads and that the significance of number of cycles, or repetitions, is relatively modest. A general principle underlying the prescription of exercise to promote bone health is Wolff’s law, which states that bone accommodates the forces applied to it by altering its amount and distribution of mass (Frost, 1990). The ability of bone to adapt to mechanical loading is much greater during growth. Adolescence is the only time in life when bone is added in substantial amounts to the inside as well as the outside of bone (Parfitt, 1994). The clinical significance of increases in bone accrual, as demonstrated above, if retained into adult, can be easily seen.

2.14 Gymnastics Training and Bone Health

As further investigations have been undertaken to determine the type of physical activity most conducive to bone accrual, gymnastics training has received significant attention. Physical activities that generate relatively high intensity loading forces, such as plyometrics, gymnastics, and high intensity resistance training have been shown to augment bone mineral accrual in adults as well as adolescents and children (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004).

Studies of the effect of post-pubertal gymnastics training on bone mineral accretion consistently demonstrate a significant positive effect. Proctor and colleagues
(2002) compared the bone mineral density of 25 elite female collegiate gymnasts (aged 18-25 years old) and a group of 25 sedentary controls. The two groups were matched for body weight; however, the gymnasts were significantly younger (-1.4 y) and shorter (-4.6 cm) than the controls. BMC and BMD were assessed using dual X-ray absorptiometry. The gymnasts were significantly leaner than the controls, as evidence by a lower percent body fat and greater lean body mass relative to the controls. The gymnasts were also found to have greater bone mineral density at all sites measured, despite numerous factors that contradict increased BMD such as delayed menarche, irregular menstrual cycles, and possible eating restraint. Whole body BMD was 8% higher in gymnasts with 18-19% differences in the lumbar spine and proximal femur, and a 17% difference in the arm. The controls demonstrated the typical pattern of slightly greater mineralization in their dominant arm, whereas bilateral differences were not evident in the upper limbs of gymnasts. This finding supports the theory that the high BMD values observed in the gymnasts were due primarily to the activity itself.

Fehling et al (1995) also examined college aged female gymnasts. They compared the bone mineral density of collegiate female athletes in impact loading sports, volleyball (n=8) and gymnastics (n=13), to active loading swimmers (n=7), and group of sedentary controls (n=17). BMC and BMD were measured using dual energy X-ray absorptiometry. The volleyball group was significantly taller and heavier than all the other groups, while the swimmers were taller than the gymnastics and control groups, but only heavier than the gymnasts; however, there were no significant differences in BMI between the groups. The volleyball players and gymnasts had significantly greater BMD than the swimmers and controls at the lumbar spine, femoral neck, Ward’s triangle, total
body, right leg, and pelvis. The BMD in the gymnastics group was significantly greater than all groups in both right and left arm despite demonstrating menstrual disturbances. There were no differences in BMD between the swimming group and the control group at any site. These results suggest that the type of mechanical loading (i.e., impact vs. active) plays an integral part in influencing BMD and that this enhancement appears to be site specific.

Few studies have examined the effects of retirement from sports involving regular, high impact, and weight-bearing activity on bone mass. However, there is some evidence that these exercise-induced gains in bone mass in children are maintained into adulthood, suggesting that physical activity habits during childhood may have long-lasting benefits on bone health (Pollock, Laing, Modlesky, O’Conner, Lewis, 2006). Zanker and colleagues (2004) studied the effect of past gymnastics participation on adult bone mass. They compared 18 former female gymnasts and 18 women who had never participated in structured sport or exercise, and explored the relationship between BMD of these former gymnasts and their duration of retirement from sport. The gymnasts had initiated training between 5 and 11 year of age and had trained continuously for between 6 and 14 years. They had retired between the ages of 15 and 22. The gymnasts displayed a broad range of duration of retirement (3-12 years) and a wide age range (20-32 years). The gymnasts had also adopted a sedentary lifestyle following retirement from gymnastics. Adoption of a sedentary lifestyle was defined as the absence of regular participation in structured exercise and a habitual physical activity level that fell below the UK recommendations of 30 min of moderate intensity activity on at least 5 days of the week. Gymnasts and controls were matched for age, body mass, and stature. BMC
and BMD were assessed using dual energy X-ray absorptiometry. The gymnasts displayed higher BMD at all measurement sites, which ranged in magnitude from 6% for total body to 11% for the total femur. In addition, there was no significant decline of BMD with increasing duration of retirement from gymnastics training.

Pollock et al. (2006) supported these findings. In their nine year follow-up study of former college gymnasts approaching menopause they found that although there were no significant differences between gymnasts and controls in percent change of BMD over a nine year period for the total body, lumbar spine, total proximal femur, femoral neck, and arm, the change in leg BMD was significantly different between the gymnastics and control groups. Gymnasts also exhibited significantly higher BMD at all sites at baseline and follow-up. The authors concluded that these college gymnasts maintained significantly higher BMD than controls 24 years after retirement from artistic gymnastics training and competition. These results suggest that an elevated bone mass in former female gymnasts is retained despite activity level and years of retirement.

In keeping with the available evidence presented in the previous section suggesting that the skeleton may be most responsive to exercise before puberty, studies have been directed at the effects of gymnastics training on prepubertal athletes. Results from several studies support the positive effect of gymnastics on bone accrual during growth. Laing and colleagues (2002) compared a small number of female gymnasts (7) to age, height, and weight matched active controls. The girls were 8-13 years of age at baseline and were followed for a 3 year period. At baseline gymnasts were training an average of 11.7 hours per week. The control group had never participated in gymnastics, training but were competitive in other activities such as basketball, soccer, softball, and
tennis. Bone measures were assessed using dual energy X-ray absorptiometry. At baseline, gymnasts were found to have greater BMD than controls at the lumbar spine, femoral neck, trochanter, total proximal femur, and total body. The girls participating in gymnastics training over the three years had enhanced rates of BMC accrual and areal BMD as well as increased fat-free mass accrual compared to the controls.

Bass et al. (1998) compared 45 prepubertal elite female gymnasts (aged 10.4 ± 0.3 years) to controls matched for skeletal age, height, and weight. BMD and body composition were measured using dual energy X-ray absorptiometry. In cross-sectional analyses, the areal BMD of the prepubertal gymnasts was 0.7-1.9 SD higher at weight-bearing sites than the predicted mean in controls. During 12 months of training, the increase in areal BMD of the total body, spine, and legs in the prepubertal gymnasts was 30-85% greater than in the prepubertal controls. Volumetric density was calculated (g/cm³); volumetric density is independent of size, providing a measure of the amount of bone in bone. The estimated volumetric BMD also increased significantly in the prepubertal gymnasts, but not in the controls. The authors concluded that increases in BMD achieved by vigorous exercise during puberty were large and potentially could reduce fracture risk in adulthood 2- to 4-fold.

Courteix and colleagues (1998) supported these findings with their study of elite prepubertal gymnasts at the starting phase of their peak bone mass accrual. The authors compared athletes involved in a sport requiring significant impact loading (gymnastics) to athletes involved in a sport with no impact loading (swimming). The sport groups consisted of 10 swimmers (aged 10.5 ± 1.4 years) and 18 gymnasts (10.4 ± 1.3 years) who had performed 3 years of high-level sport training (8-12 h/wk for swimmers and 10-
15 h/w for gymnasts). Thirteen girls (10.7 ± 1.0 y) involved in fewer than 3 hours per week of activity served as a control group. There were no significant differences between the groups with regard to age, weight, height, or body composition. Mean BMD in gymnasts was significantly higher than in the control group and above normative values. Courteix et al. concluded that physical activity in childhood could be an important factor in bone mineral acquisition in prepubertal girls, but only if the sport can induce bone strains during a long-term program. Gymnasts have been found to not only have increased cross-sectional BMD values at the lumbar spine, proximal femur, and total body; these young athletes have also been found to increase BMD at a greater rate than controls (Nickols-Richardson, et al., 1999). Nickols-Richardson et al. (1999) concluded that gymnastics training in childhood maximizes peak BMD.

Total hours of weight bearing activity have been found to correlate significantly with BMC and BMD in normal children. Dramatic increases in bone parameters as a result of high impact loading have been observed in the years surrounding peak bone mineral accrual in adolescents. Gymnasts, in particular, who have been actively engaged in training for 4 or more years have been found to have greater BMC and BMD values from approximately 10 years of age onward. However, many studies of gymnasts are retrospective, do not focus specifically on prepubertal children, and use BMD as their measure of comparison (Faulkner, Bailey, Drinkwater, McKay, Arnold, & Wilkinson, 1996). BMD is an areal density and is dependent on bone size. When comparing children whose bones may be changing size rapidly, confusion can result about the magnitude of change in BMD during the growing years (Compston, 1995). Mineralization and area do not change at the same rate in growing children. The
influence of size dependent variables can lead to over or underestimation of BMD. Therefore, the current investigation examined BMC and BMD with height and weight treated as covariates. There is evidence that physical activity may affect bone at an early age, but we do not know when the differences in gymnasts BMC and BMD become apparent.

2.15 Summary

The antecedents of adult diseases such as cardiovascular disease, diabetes, and osteoporosis, have been linked to body composition development (fat and bone tissue) in childhood. Overweight and obesity are caused by a positive energy balance – more calories are consumed than expended. These conditions are influenced by either high energy intake, low energy expenditure, or a combination of the two. A significant body of research suggests that body composition (fat and bone tissue) in children can be affected through physical activity (Bar-Or & Baranowski, 1994; Garaulet, et al, 2000; Maffeis, et al, 1996). However, the exact relationship between physical activity and a healthy body composition as well as the age when differentiation occurs remain unclear. The observation that Canadian children and adults are becoming progressively more obese and that this obesity is linked to many health conditions is not a new discovery; however, few data have been collected to indicate how, why, or when children become overweight or obese.

Since gymnastics is a sport associated with increased lean rather than fat mass, I hypothesized that gymnastics training at a young age should reduce AR and thus result in a decreased fat mass in these individuals. The literature that currently exists; however, focuses on adolescent and retired gymnasts with a few studies on prepubescent children.
7-10 years of age, and nothing in the preschool age group. In addition, the majority of the previous studies have examined children considered to be elite athletes training a minimum of 4 hours/week. The aim of the current study is to investigate whether these phenomena are also observed in young children participating in fewer hours of gymnastics training. It is likely that gymnastics training not only results in an increase in the amount of time involved in physical activity, but also decreases the amount of time spent doing sedentary activities; therefore, I hypothesize that gymnastics training will result in decreased fat mass.

Exercise during growth may also contribute to the prevention of osteoporosis by increasing the amount bone mineral content accrued in adolescence. Although the long term implications of physical activity on bone health are not yet well defined, it is prudent that public health strategies aimed at optimizing lifestyle choices be developed and implemented for children and youth (Faulkner & Bailey, 2007). There is growing evidence to support the assertion that bone mineral density in prepubertal children increases as a result of high-impact aerobic and strength building or weight-bearing exercise; however, little research has been conducted on the effects of impact loading activity and specifically gymnastics training on male athletes. Gymnastics training involves uniquely high mechanical loading on the skeleton. These loading forces have been shown to be up to 10 times body weight on the hands and feet with over 700 foot contacts and over 100 hand contacts in a typical 4-hour training session (Mafukidze, 2000). Because of this high loading, gymnasts are an optimal population to study the effects of physical activity on bone adaptation. Girls begin training between 5-7 years of age and are often training between 24-36 hours a week by age 10.
It has also been reported that some gymnasts may restrict their total caloric intake and experience delayed menarche, which have been shown to have a negative impact on bone mineral density (Kirchner, Lewis, & O’Conner, 1995). Intense physical training leads to an increase in energy expenditure; this coupled with the increasing dominant smaller-sized physique of female gymnasts, who are beginning training at earlier ages, has prompted debate as to whether these conditions inhibit growth and development.

While it is likely that the type of physical activity in which competitive gymnasts engage provides a high mechanical stimulus to bone mineralization, a high percentage of these athletes may also engage in behaviors that theoretically would have a negative influence on BMD.

Little evidence has been collected on gymnasts under 7-8 years of age, thus the question of nature or nurture always arises; that is, are gymnasts’ bones denser because they are involved in gymnastics or are they gymnasts because they have denser bones? The current study aims to examine this question by observing children in early childhood, 4-6 years of age, before systematic training has begun. The majority of the gymnastics literature has also focused on females; little information has been collected on the effects of gymnastics training on BMC and BMD development in males. Osteoporosis in elderly men is becoming a major public health problem (Szule & Delmas, 2007). Currently 25-30% of fragility fractures occur in men (Baron, Karagas, Barrett, Kniffin, Malenka, Mayor & Kellet, 1996). Post fracture morbidity and mortality have also been found to be higher in men than women (Fransen, Woodward, Norton, Robinson, Butler, Campbell, 2002). As the incidence of osteoporosis in males continues to increase it is important to find ways to combat this disease in both genders. The aim of this study is to examine both
males and females in early childhood (aged 4-6 yrs) to determine the effects of early
weight-bearing structured physical activity (gymnastics participation) on bone mineral
accrual.

2.16 Hypotheses

(1). Children involved in structured physical activity (gymnastics) will have a
lower fat mass compared to children who do not participate in gymnastics.

(2). Children involved in weight bearing physical activity (gymnastics) will have
higher bone mineral content compared to children who do not participate in gymnastics.
3.0 METHODS:

3.1 Research Design:

A cross-sectional comparison of two independent samples was used. This study was approved by the University of Saskatchewan’s Biomedical Research Ethics Board (Bio 06-111) (Appendix A). All parents provide written consent and participants provided verbal ascent. If at any time during the testing procedure a subject refused to participate in a stage of the assessment that stage was simply not performed and remainder of the assessment that the subject would participate in was completed. All measurements of individual subjects took place on the same day in College of Kinesiology at the University of Saskatchewan. All data were collected between August 2006 and March 2007.

3.2 Participants:

One hundred and fifty eight healthy male and female subjects between the ages of 4 and 6 years were recruited. Participants included 63 beginner and pre-competitive gymnasts and 95 active control children. The control children were involved in other activities such as swimming, hockey, and soccer, but were not participating in gymnastics training. The number of children in each group by age is shown in Table 3.1.

<table>
<thead>
<tr>
<th>Age</th>
<th>Males Controls</th>
<th>Males Gymnasts</th>
<th>Females Controls</th>
<th>Females Gymnasts</th>
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<tr>
<td>4 years</td>
<td>19</td>
<td>9</td>
<td>12</td>
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<td>5 years</td>
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<td>6 years</td>
<td>16</td>
<td>6</td>
<td>22</td>
<td>16</td>
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<tr>
<td>Totals</td>
<td>49</td>
<td>25</td>
<td>46</td>
<td>38</td>
</tr>
</tbody>
</table>
The smaller number of participants in the male gymnast group is a reflection of the lower participation rate of young males in this sport. Previous studies have shown that many young children participate in gymnastics; therefore, it was thought that there should be a wide base of children from which to recruit (Baxter-Jones & Helms, 1996). However, sample size was limited by the number of children in Saskatoon participating in gymnastics.

Gymnasts were recruited from the pre-competitive programs of three nationally ranked gymnastics clubs in Saskatoon and the city’s university recreational gymnastics program. The control group was recruited from the learn-to-swim program at the University of Saskatchewan. It should be noted that the members of the control group were not competitive or pre-competitive swimmers, but rather were enrolled in a learn-to-swim program which is aimed at teaching kids to swim for safety reasons. Generally, mothers have been found to register their children in swimming for the safety aspect whereas they register their children in gymnastics for physical activity motives (Baxter-Jones, Maffulli, 2003). Recruitment posters (Appendix B) were displayed at these locations and information was given to parents during lesson times. Individuals were asked to contact the researchers if they were interested in participating. Parent information sessions were also held for interested parties. Coaches and instructors were not informed of which individuals chose to participate and which chose not to participate in order to safeguard the children from any possible harmful consequences of not participating.

All participants were volunteers who met the entry criteria. Participants were excluded if they had any conditions that prevented them from performing exercise safely
(ie., heart conditions, musculo-skeletal problems). Informed consent was obtained from all parents or guardians and verbal assent was obtained from all children (Appendix C).

3.3 Chronological Age

The chronological age of each subject was recorded to the nearest 0.01 year by subtracting the decimal year of the subject’s date of birth from the decimal year of the day of testing. To create standardized chronological age groups, subjects were then classified into age groups at the time of measurement. For example, all children who were between 3.50 years and 4.49 years on the date of measurement were classified as 4 years of age.

3.4 Anthropometric Measures

Anthropometric measurements included height, weight, sitting height, waist circumference and skinfold measures. The height of each child was measured using a stadiometer, and body mass was measured using a digital standard physician’s scale. Triceps, biceps, subscapular, suprailiac, and calf skinfolds were measured to the nearest 0.2 mm with a Harpenden skinfold caliper and a sum of all 5 sites was calculated. Waist circumference (cm) was measured midway between the 10th rib and the top of the iliac crest. Waist circumference was measured as an indicator of central adiposity and the sum of 5 skinfolds as an indicator of subcutaneous fat mass, as DXA measurements were not available for all individuals. All measures were performed by the same Certified Exercise Physiologist. Children were measured in a nonfasting condition while wearing light clothing without shoes. Heights were recorded to the nearest millimeter and body mass to the nearest 0.5 kilogram. BMI was calculated by dividing weight in kg by height.
Birth weight (lbs) was also reported by the parent completing the physical activity questionnaire, generally the mother.

Mothers’ and Fathers’ heights and weights were self-reported. All self-reported heights were adjusted for the tendency of individuals to overestimate height. The following equation was used: 2.316 + (0.955 * reported height in inches) (Epstein, Valoski, Kalarchain, & McCurley, 1995).

### 3.5 Physical Activity Assessment

Physical activity was assessed using The Netherlands Physical Activity Questionnaire (NPAQ) (Appendix D). Parents were asked to report their child’s current physical activity. The NPAQ proxy report was originally designed to be completed by parents or teachers and includes items about activity preferences and everyday activity choices rather than a specific recall of physical activity (Montoye, Kemper, Saris, & Washburn; 1996). The questionnaire captures usual physical activity patterns that sort children into low and high movement categories. The NPAQ consists of seven Likert-type responses (1-5 scale) that are averaged for a total score. Typically, the NPAQ required less than 5 minutes to complete. Previous work by Saris and colleagues with 4-6 year old children indicate that the questionnaire score discriminated between low and high levels of physical activity when compared to a criterion measure of pedometry (Saris & Binkhorst, 1997; Saris, Binkhorst, Cramwinckle, van Waesberghe & vander Veen-Hezemans, 1980). Janz and colleagues (2005) compared the NPAQ to accelerometer data and found moderate to good test-retest reliability (R = 0.7) of the NPAQ and moderate concurrent validity. Using trilogistic regression they have shown that the NPAQ can be used to classify children into low and high activity groups.
approximately 70% of the time (Janz, Broffitt, Levy, 2005). This suggests moderate to good validity for grouping of children.

In response to the secular increase in young children’s sedentary activity; Janz and colleagues modified the questionnaire to include a parental report of children’s usual hours spent watching television and playing computer and video games each day. Previous research indicates parental reports of children’s TV watching to be positively associated with adiposity (Anderson, Field, Collins, Lorch, Nathan, 1985; Dietz, & Gortmaker, 1985). Anderson et al. (1985) compared parental reports of 5-year old children’s TV viewing with concurrent automated time-lapse video observations and found strong agreement (r = 0.84) and a small absolute mean time error. TV viewing will be used as a measure of sedentary behavior, as Janz et al. (2002) found that sedentary behavior may have a detrimental effect on children’s adiposity independent of physical activity levels. They also examined the measurement properties of a proxy recall for TV viewing. The results suggested evidence for good reliability (R = 0.7) for television viewing (Janz, et al., 2005). Janz and colleagues (2005) concluded that parental proxy reports using NPAQ and TV viewing provide simple and practical measures of everyday physical activity preferences and choices in young children.

3.6 Dietary Evaluation

All dietary records were completed by the same parent or guardian and consisted of a 24-hour recall (Appendix E). Parents received an initial training session on food-portion sizes. Display boards of life-size two-dimensional pictures of food portions (National Dairy Board, 1990. Rosemont, Illinois) were presented at the time of recall. For the 24-hour recall the parent was asked to recall all the food intake of their child for the
previous 24 hours. A detailed description of all food and beverages consumed, including
the preparation methods, when the foods were eaten, and brand names were recorded.
Intake data were analyzed and tabulated using the Food Processor Nutrition and Fitness
Software version 8.5 (ESHA research software, Salem, Oregon). Linneman and
colleagues (2004) found that parents accurately reported their children’s intake of fruit
and vegetables 24 hours after consumption (r = 0.61).

3.7 Body Composition Measures

Body composition measurements were performed at the University of
Saskatchewan, College of Kinesiology using a Hologic Discovery Wi dual energy x-ray
absorptiometry (DXA) unit. The principle behind the operation of DXA is the absorption
of ionizing radiation by body tissue (Lai, Goodsitt, Murano, & Chesnut, 1992). When
radiation is passed through the body the amount that the radiation is reduced is related to
the amount of tissue present. Since the radiation absorption characteristics of bone, lean,
and fat tissue are different from one another, the loss of energy from the x-rays allows
calculation of body composition (Hologic, 1992). With DXA, a series of transverse scans
are made of the whole body at 1-cm intervals differentiating the body tissues into fat
tissue, lean tissue, and bone mass.

The specific variables derived from the DXA scans were percent body fat, fat
mass, bone mineral content (BMC), bone mineral density (BMD) and total body mass.
The terms BMC and BMD are often used interchangeably and the difference between
them overlooked; however, this difference is important, particularly when comparing
bone of different size. BMC refers to the total grams of bone mineral within a measured
bone region (i.e, totally body, lumbar spine). BMD refers to the grams of bone mineral
per unit of bone. For example, when comparing bone mineral in two athletes, the larger person will have greater BMC even if her BMD is lower. Interpretation of results in growing children is problematic since bone mineral accretion during childhood is dependent on, and highly correlated with growth and puberty (Warner, Cowan, Dunstan, Evans, Webb, & Gregory, 1998). If this is not considered, one may draw incorrect conclusions about bone mineral; this is especially important in this study as we are using children of different ages and thus sizes. The use of adjusted values for BMC allows comparison of values in subjects with a wide range of body sizes and ages, and does not include assumptions about the shape of the bone (Warner et al., 1998). Therefore, the current investigation will incorporate size, height, and weight, into the model when assessing BMC and BMD.

DXA is the most widely used technique for assessing body composition because of its low precision error, its low radiation exposure, its ability to provide data regarding soft tissue composition as well as bone mineral, and its capacity to measure multiple skeletal sites in both the axial and appendicular skeleton (Miller, Bonnick, and Rosen, 1995; Khan, et al., 2001). Reliability between scans is achieved using phantom calibration. Short-term intra-machine reliability has been shown to have a coefficient of variation (CV) of 0.42%-1.7% (Rencken, Murano, Drinkwater, & Chesnut, III, 1991; Mazess, Barden, Bisek, & Hanson, 1990; Mazess, et al., 1989; Chan, 1992) and long-term intra-machine reliability has been shown to have a CV of 0.4-0.6% (Rencken et al., 1991; Mazss et al., 1989). The Hologic Discovery Wi DXA used in our lab has been found to have a CV of approximately 1% for lumbar spine and whole body BMC and
BMD and CV of 1.5% for hip BMC and BMD as well as a CV of 3% for total body fat based on duplicate measures in young females (20-30 y).

Elowsson et al. (1998) found DXA to be accurate and precise as a measure of body composition when compared to carcass analysis of pigs within children’s body weight ranges (r = 0.90 – 1.0). DXA scanning times, which may have been an impediment to its use in pediatric studies, have decreased substantially with newer technology (Miller, et al., 1995). Therefore, DXA is the principle method of assessing skeletal status in children (Faulkner & Bailey, 2007). Recently, the American Society of Bone and Mineral Research Pediatric One Initiative Group (2005) recommended that, pending the development of more accurate and safe equipment, data from DXA remain the modality of choice for the near future.

The total radiation per DXA session is less than 10 millirem (mrem) which is similar to the background radiation one would receive making a return flight from Saskatoon to Halifax on a commercial airline. For comparison purposes, the average annual background radiation in Saskatoon due to natural sources is approximately 150 mrem per year. The typical exposure from a routine dental x-ray is over 50 mrem. These values can be used to compare the relative risk of less than 10 mrem exposure from the DXA scan. All scans were administered and analyzed by a certified radiology technologist and parents were present at the time of scanning.

Participants wore clothing with no metal zippers or buttons. All jewelry, belts, glasses, hair clips, footwear, and anything else containing metal were removed. Height, weight, gender and age were recorded on hospital forms and entered into the Hologic system file prior to commencement of the scan. Quality control phantom scans were
performed daily. Three different scans were performed; whole body, lumbar spine, and proximal femur (hip).

3.7.1 Total Body Protocol

To collect total body BMC and BMD the body was centered and straightened along the midline within the rectangular region outlined for the total body on the scan mat. The head was positioned with the chin raised and the shoulders depressed. This prevents the overlap of the mandible and the superior aspect of the scapula on the scanned image. The hands were prone and equidistant from the torso on either side of, but not touching, the body. Feet were internally rotated with the great toes touching and then taped to immobilize the feet and eliminate tibia and fibula overlap during the scan. Due to the short stature of the young participants the scan distance was shortened from 187 cm to the participant’s height plus 20 cm, to ensure the whole body was scanned. The total body scan took between two and four minutes depending on the participant’s height.

3.7.2 Lumbar Spine Protocol

The participant was centered along the midline with equidistance from the head and foot of the scan mat in a supine position. The spine was positioned in a straight line along the solid marker in the center of the scan mat. To remove the arms from the scan zone and raise the ribs away from the region of interest the participant’s hands were placed behind their head. A small box was placed beneath the participant’s lower legs to reduce the natural lordotic curve of the lumbar spine and to place the spine in contact with the table. The participant was asked to remain as still as possible during the scan which took approximately 30 seconds.
3.7.3 Total Hip Protocol

For the left total hip scan, the participant was once again positioned in straight line supine position on the scan mat. The left foot was then inverted approximately 30 degrees and strapped to a positioning wedge with a nylon belt. The participant’s arm was positioned outside of the scan region. Total scan time was approximately 10 seconds.

3.8 Statistical Analysis

Variables are presented as means and standard deviations. Heights and weights were compared to age and gender reference standards (CDC, 2000). The percentage of overweight and obese children in each group was calculated using Cole’s cut points (2000). Mean differences were tested using the following strategy: (i) Group differences (gymnasts vs. controls) were tested for using independent T-tests. (ii) To account for possible confounders mean differences were compared by gender (male, female), age (4, 5 and 6 years) and group (gymnasts, controls) using a 2x3x2 factorial ANOVA with Bonferroni post hoc analysis. (iii) If age and gender were found to be confounders, then adjusted group means were compared using an ANCOVA (controlling for confounding variables). A MANOVA was performed if multiple dependent variables were identified. Correlations between variables were assessed using Bivariate Pearson correlations. As a general rule an r value of 0.5-0.7 is considered low, 0.7-0.8 moderate and a value of 0.9 or greater is considered good (Vincent, 2005). All analyses were performed using SPSS version 15.0. Alpha was set as $p<0.05$. 
4.0 RESULTS

4.1 Descriptive Data

Figure 4.1 illustrates mean age data plotted against the CDC (2000) reference curves for height and weight for males and females. The 50th percentile line represents the average height and weight for normal healthy children at that age. An individual above the 95th percentile or below the 5th percentile may be cause for concern for growth disorders. It was found that all subjects, gymnasts and controls, fell within the normal ranges, very close to the 50th centile. Further more, both males and females appear to follow the general curve of normal growth, that is, heights and weights increasing with increasing age. A factorial ANOVA revealed that if the effects of age and gender were ignored then gymnasts were on average 3.2 cm shorter than controls.

Figure 4.1 – Gymnasts’ and controls’ heights and weights vs. CDC growth reference standards (2000)
The subjects’ demographic details are shown in Table 4.1. There were no significant differences (p>0.05) between the groups with regard to any of the variables for either gender. Results of the group by age by gender factorial ANOVA’s revealed no significant interactions (p>0.05) for any of the variables in Table 4.1, apart from calories consumed per day. There was a significant main effect of age for minutes per day watching TV ($f_{11,144} = 5.464, p<0.05$) and minutes per day playing video games ($f_{11,144} = 6.135, p<0.05$); indicating that the older children spent increased minutes per day watching TV and playing video and computer games. The group by age interaction found for calories consumed per day ($p<0.05$) indicated that gymnasts decreased their energy intake between 4-5 years of age followed by an increase between 5 and 6 years of age, in contrast to controls increased their energy intake between 4-5 years followed by a decrease between 5 and 6 years. Thus, the groups responded differently over time with regard to energy intake.
Table 4.1 – Demographic characteristics of gymnasts and controls

| Characteristics | Males | | | | | | | | | | Males | | | | | | | | | | Females | | | | | | | | | |
| Mother’s Ht (cm) | 165.3 ± 7.4 | 165.2 ± 5.8 | 166.4 ± 6.9 | 166.4 ± 8.1 | (48) | (23) | (45) | (38) |
| Mother’s Wt (kg) | 66.6 ± 11.4 | 69.9 ± 13.2 | 66.6 ± 15.0 | 67.4 ± 13.4 | (48) | (23) | (42) | (38) |
| Mother’s BMI (kg/m²) | 24.9 ± 3.6 | 25.7 ± 8.7 | 24.8 ± 5.4 | 25.3 ± 4.7 | (44) | (23) | (43) | (37) |
| Father’s Ht (cm) | 179.0 ± 6.2 | 179.0 ± 8.8 | 180.0 ± 7.4 | 178.0 ± 7.2 | (47) | (23) | (46) | (38) |
| Father’s Wt (kg) | 87.7 ± 15.3 | 88.7 ± 17.0 | 84.6 ± 12.8 | 87.3 ± 14.7 | (47) | (23) | (46) | (36) |
| Father’s BMI (kg/m²) | 28.5 ± 5.6 | 27.2 ± 4.6 | 26.7 ± 4.5 | 28.7 ± 5.1 | (42) | (24) | (42) | (39) |
| Birth Wt (lbs) | 7.6 ± 1.0 | 8.1 ± 1.2 | 7.3 ± 1.3 | 7.1 ± 1.3 | (49) | (24) | (46) | (35) |
| P.A Score | 25.4 ± 3.8 | 24.0 ± 2.9 | 23.7 ± 3.2 | 25.0 ± 2.7 | (49) | (25) | (46) | (36) |
| TV min/day | 93.5 ± 51.5 | 101.0 ± 48.8 | 98.6 ± 75.9 | 104.0 ± 57.7 | (49) | (25) | (46) | (36) |
| Video min/d | 19.1 ± 30.7 | 18.2 ± 22.5 | 15.9 ± 20.1 | 10.4 ± 16.7 | (49) | (25) | (46) | (36) |
| Cal/day (kcal) | 1732.8 ± 733.4 | 1517.1 ± 558.7 | 1555.0 ± 423.6 | 1616.5 ± 558.7 | (48) | (24) | (46) | (35) |

Mean values are presented ± the standard deviation and (n).
No significant differences between groups were found.

With regard to training hours male gymnasts were found, on average, to participate 1.1 ± 0.7 hours per week (0.75-4.0 hrs) with the majority (90.5%) training for one hour or less. Male gymnasts had participated, on average, for 1.9 ± 1.1 years (0.25-4.0) prior to being assessed, with the majority (95.2%) starting before 5 years of age.

Female gymnasts, on average, participated 1.9 ± 1.9 hours per week (0.5-7.5 hrs) with over two thirds (76.5%), training two or less hours per week. Female gymnasts, on average, had been participating for 2.1 ± 1.1 years (0.25-4) prior to study entry, the majority (91.2%) starting before the age of 5.
4.2 Analysis of Group Differences in Fat Parameters

The data presented in Table 4.2 represents the percentage of children in each group considered to be overweight and obese as defined by Cole et al. (2000). When all the data were pooled, 79.6% of subjects were normal weight, 17.8% overweight and 2.5% classified as obese.

Table 4.2 – Percentage of children classified as overweight and obese based on BMI using definitions developed by Cole and colleagues (2000)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Gymnasts</td>
</tr>
<tr>
<td>Normal Wt</td>
<td>77.6% (38)</td>
<td>79.2% (19)</td>
</tr>
<tr>
<td>Overweight</td>
<td>20.4% (10)</td>
<td>20.8% (5)</td>
</tr>
<tr>
<td>Obese</td>
<td>2.0% (1)</td>
<td>0% (0)</td>
</tr>
</tbody>
</table>

Table 4.3 shows the mean values for the fat mass parameters by gender and group. There were no significant group differences for any of the variables with the exception of BMI in males ($p<0.05$) and extremity fat in females ($p<0.05$). Results of the factorial ANOVA showed no significant differences between groups at any age for any variables. There were significant main effects of age for BMI ($f_{12,145} = 14.48, p<0.05$), waist circumferences ($f_{11,146} = 6.89, p<0.05$), and percent body fat ($f_{11,128} = 10.24, p<0.05$); indicating that older children had increased BMI, waist circumference and percent body fat. There were also significant main effects of gender for BMI ($f_{12,145} = 5.59, p<0.05$), trunk fat ($f_{11,128} = 6.52, p<0.05$), and percent body fat ($f_{11,128} = 21.99, p<0.05$). Males had a significantly higher BMI while females had significantly more trunk fat and a greater percent body fat than males. Since no group differences were present the analysis was concluded at this stage.
### Table 4.3 – Measures of fat mass indicators in gymnasts and controls

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Gymnasts</td>
<td>Controls</td>
<td>Gymnasts</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>16.1 ± 1.4* (49)</td>
<td>16.9 ± 1.5* (25)</td>
<td>16.0 ± 1.3 (47)</td>
<td>15.9 ± 1.3 (38)</td>
</tr>
<tr>
<td>Females</td>
<td>16.9 ± 1.5* (25)</td>
<td>16.0 ± 1.3 (47)</td>
<td>15.9 ± 1.3 (38)</td>
<td>16.0 ± 1.3 (47)</td>
</tr>
<tr>
<td><strong>Waist Circumference(cm)</strong></td>
<td>54.2 ± 3.7 (49)</td>
<td>53.3 ± 4.3 (25)</td>
<td>53.7 ± 4.6 (47)</td>
<td>52.8 ± 3.9 (38)</td>
</tr>
<tr>
<td>Males</td>
<td>53.3 ± 4.3 (25)</td>
<td>53.7 ± 4.6 (47)</td>
<td>52.8 ± 3.9 (38)</td>
<td>53.3 ± 4.3 (25)</td>
</tr>
<tr>
<td>Females</td>
<td>53.7 ± 4.6 (47)</td>
<td>52.8 ± 3.9 (38)</td>
<td>53.3 ± 4.3 (25)</td>
<td>53.7 ± 4.6 (47)</td>
</tr>
<tr>
<td><strong>Sum of 5 Skfs (mm)</strong></td>
<td>31.3 ± 6.5 (47)</td>
<td>34.1 ± 6.9 (20)</td>
<td>36.9 ± 10.9 (39)</td>
<td>34.9 ± 8.2 (32)</td>
</tr>
<tr>
<td>Males</td>
<td>34.1 ± 6.9 (20)</td>
<td>36.9 ± 10.9 (39)</td>
<td>34.9 ± 8.2 (32)</td>
<td>34.1 ± 6.9 (20)</td>
</tr>
<tr>
<td>Females</td>
<td>36.9 ± 10.9 (39)</td>
<td>34.9 ± 8.2 (32)</td>
<td>34.1 ± 6.9 (20)</td>
<td>36.9 ± 10.9 (39)</td>
</tr>
<tr>
<td><strong>Body Fat (DEXA) (kg)</strong></td>
<td>43.1 ± 11.3 (42)</td>
<td>44.9 ± 11.4 (21)</td>
<td>50.1 ± 14.6 (41)</td>
<td>44.7 ± 10.4 (36)</td>
</tr>
<tr>
<td>Males</td>
<td>44.9 ± 11.4 (21)</td>
<td>50.1 ± 14.6 (41)</td>
<td>44.7 ± 10.4 (36)</td>
<td>44.9 ± 11.4 (21)</td>
</tr>
<tr>
<td>Females</td>
<td>50.1 ± 14.6 (41)</td>
<td>44.7 ± 10.4 (36)</td>
<td>44.9 ± 11.4 (21)</td>
<td>50.1 ± 14.6 (41)</td>
</tr>
<tr>
<td><strong>Trunk Fat (kg)</strong></td>
<td>13.7 ± 3.9 (42)</td>
<td>15.0 ± 5.3 (21)</td>
<td>17.4 ± 6.3 (41)</td>
<td>15.9 ± 4.7 (36)</td>
</tr>
<tr>
<td>Males</td>
<td>15.0 ± 5.3 (21)</td>
<td>17.4 ± 6.3 (41)</td>
<td>15.9 ± 4.7 (36)</td>
<td>15.0 ± 5.3 (21)</td>
</tr>
<tr>
<td>Females</td>
<td>17.4 ± 6.3 (41)</td>
<td>15.9 ± 4.7 (36)</td>
<td>15.0 ± 5.3 (21)</td>
<td>17.4 ± 6.3 (41)</td>
</tr>
<tr>
<td><strong>Extremity Fat (kg)</strong></td>
<td>22.1 ± 7.6 (42)</td>
<td>23.4 ± 6.6 (21)</td>
<td>27.0 ± 8.6* (41)</td>
<td>22.9 ± 5.8* (36)</td>
</tr>
<tr>
<td>Males</td>
<td>23.4 ± 6.6 (21)</td>
<td>27.0 ± 8.6* (41)</td>
<td>22.9 ± 5.8* (36)</td>
<td>23.4 ± 6.6 (21)</td>
</tr>
<tr>
<td>Females</td>
<td>27.0 ± 8.6* (41)</td>
<td>22.9 ± 5.8* (36)</td>
<td>23.4 ± 6.6 (21)</td>
<td>27.0 ± 8.6* (41)</td>
</tr>
<tr>
<td><strong>% Fat</strong></td>
<td>21.2 ± 4.3 (42)</td>
<td>22.4 ± 4.3 (21)</td>
<td>25.6 ± 5.4 (41)</td>
<td>24.1 ± 4.3 (36)</td>
</tr>
<tr>
<td>Males</td>
<td>22.4 ± 4.3 (21)</td>
<td>25.6 ± 5.4 (41)</td>
<td>24.1 ± 4.3 (36)</td>
<td>22.4 ± 4.3 (21)</td>
</tr>
<tr>
<td>Females</td>
<td>25.6 ± 5.4 (41)</td>
<td>24.1 ± 4.3 (36)</td>
<td>22.4 ± 4.3 (21)</td>
<td>25.6 ± 5.4 (41)</td>
</tr>
</tbody>
</table>

Mean values are presented ± the standard deviation and (n).

* Significant difference between groups

** Significant difference between genders

Relationships between lifestyle parameters and fat mass parameters are presented in Table 4.4. Physical activity was found to be negatively correlated with percent fat. TV viewing was found to be positively correlated with sum of 5 skinfolds, extremity fat, and percent fat. However, the correlations would be considered very low (<0.5). The physical activity score, minutes per day spent watching TV and playing video games, as well as total energy intake were not correlated with the remaining fat mass variables examined.
Table 4.4 – Pearson correlations between fat variables and lifestyle parameters

<table>
<thead>
<tr>
<th></th>
<th>BMI (kg/m²)</th>
<th>W.C. (cm)</th>
<th>Sum of 5 Skfs (mm)</th>
<th>Body Fat (kg)</th>
<th>Trunk Fat (kg)</th>
<th>Extremity Fat (kg)</th>
<th>% Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.A Score</td>
<td>0.00</td>
<td>0.131</td>
<td>-0.137</td>
<td>-0.099</td>
<td>-0.06</td>
<td>-0.099</td>
<td>-0.226</td>
</tr>
<tr>
<td></td>
<td>(0.996)</td>
<td>(0.103)</td>
<td>(0.112)</td>
<td>(0.246)</td>
<td>(0.486)</td>
<td>(0.250)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>TV min/day</td>
<td>0.065</td>
<td>0.085</td>
<td>0.267</td>
<td>0.158</td>
<td>0.144</td>
<td>0.191</td>
<td>0.319</td>
</tr>
<tr>
<td></td>
<td>(0.419)</td>
<td>(0.291)</td>
<td>(0.002)</td>
<td>(0.064)</td>
<td>(0.092)</td>
<td>(0.026)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Video min/d</td>
<td>0.043</td>
<td>0.114</td>
<td>0.067</td>
<td>0.052</td>
<td>0.029</td>
<td>0.045</td>
<td>-0.107</td>
</tr>
<tr>
<td></td>
<td>(0.595)</td>
<td>(0.073)</td>
<td>(0.441)</td>
<td>(0.548)</td>
<td>(0.737)</td>
<td>(0.605)</td>
<td>(0.213)</td>
</tr>
<tr>
<td>Cal/day (kcal)</td>
<td>-0.009</td>
<td>0.132</td>
<td>0.014</td>
<td>0.045</td>
<td>-0.014</td>
<td>0.141</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td>(0.909)</td>
<td>(0.104)</td>
<td>(0.872)</td>
<td>(0.630)</td>
<td>(0.871)</td>
<td>(0.104)</td>
<td>(0.394)</td>
</tr>
</tbody>
</table>

Pearson correlation r values are presented as well as the significance level (p-value) in brackets.

4.3 Analysis of Group Differences in Bone Parameters

Area, BMC, and BMD (means ± SD) for total body, hip, and spine are presented in Table 4.5. No significant differences (p>0.05) between the groups with regard to any of the variables were found for either gender. Results of the factorial ANOVA (age x gender x group) revealed no significant differences between the groups at any age with regard to any of the variables. As expected, there were significant main effects of age for total body area ($f_{12,128} = 30.79, p<0.05$), total body BMC ($f_{11,128} = 23.68, p<0.05$), total body BMD ($f_{11,139} = 21.18, p<0.05$), spine area ($f_{11,123} = 15.49, p<0.05$), spine BMC ($f_{11,123} = 19.39, p<0.05$), and hip BMD ($f_{11,110} = 4.32, p<0.05$), indicating that BMC and BMD were increasing with age. It was also found that males had significantly greater total body BMC ($f_{11,128} = 8.24, p<0.05$), total body BMD ($f_{11,139} = 14.90, p<0.05$), spine area ($f_{11,123} = 13.89, p<0.05$), spine BMC ($f_{11,123} = 4.73, p<0.05$), and hip BMD ($f_{11,110} = 7.43, p<0.05$), when the age and group effects were ignored.
Table 4.5 – Comparison of bone measures between gymnasts and controls as measured by DXA

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Gymnasts</td>
</tr>
<tr>
<td>Total Body Area (cm²)</td>
<td>1048.4 ± 90.8 (42)</td>
<td>1038.9 ± 90.9 (21)</td>
</tr>
<tr>
<td>Total Body BMC (g)</td>
<td>705.0 ± 122.2 (42)</td>
<td>685.8 ± 104.7 (21)</td>
</tr>
<tr>
<td>Total Body BMD (g/cm²)</td>
<td>0.67 ± 0.06 (42)</td>
<td>0.66 ± 0.05 (21)</td>
</tr>
<tr>
<td>Spine Area (cm²)</td>
<td>31.7 ± 4.0 (41)</td>
<td>31.9 ± 4.6 (19)</td>
</tr>
<tr>
<td>Spine BMC (g)</td>
<td>16.0 ± 3.3 (41)</td>
<td>16.1 ± 2.7 (19)</td>
</tr>
<tr>
<td>Spine BMD (g/cm²)</td>
<td>0.50 ± 0.05 (41)</td>
<td>0.50 ± 0.05 (19)</td>
</tr>
<tr>
<td>Hip Area (cm²)</td>
<td>15.8 ± 4.2 (38)</td>
<td>14.5 ± 2.8 (17)</td>
</tr>
<tr>
<td>Hip BMC (g)</td>
<td>9.4 ± 2.8 (38)</td>
<td>8.4 ± 1.8 (17)</td>
</tr>
<tr>
<td>Hip BMD (g/cm²)</td>
<td>0.58 ± 0.08 (38)</td>
<td>0.59 ± 0.06 (17)</td>
</tr>
</tbody>
</table>

Mean values are presented ± the standard deviation and (n).

a Significant difference between genders

No significant differences were found for any of the parameters compared between the two groups within each sex.

Pearson correlations (Table 4.6) were performed between the bone parameters and lifestyle parameters. The physical activity score was found to be positively correlated with total body (TB) area, TB BMD, spine area, spine BMC, spine BMD, and hip BMD while TV viewing was negatively correlated with TB BMD, spine BMC, and spine BMD. Unexpectedly, minutes spent playing video or computer games were positively correlated with TB area and TB BMD. However, all correlations would be considered very low (<0.5). Diet as expressed by Kcal consumed per day was not correlated with any bone parameter.
Table 4.6 – Pearson correlations for bone parameters and lifestyle parameters

<table>
<thead>
<tr>
<th></th>
<th>TB area</th>
<th>TB BMC</th>
<th>TB BMD</th>
<th>Spine area</th>
<th>Spine BMC</th>
<th>Spine BMD</th>
<th>Hip area</th>
<th>Hip BMC</th>
<th>Hip BMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.A Score</td>
<td>0.174</td>
<td>0.146</td>
<td>0.184</td>
<td>0.182</td>
<td>0.219</td>
<td>0.173</td>
<td>-0.011</td>
<td>0.031</td>
<td>0.183</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.088)</td>
<td>(0.031)</td>
<td>(0.036)</td>
<td>(0.01)</td>
<td>(0.05)</td>
<td>(0.98)</td>
<td>(0.734)</td>
<td>(0.045)</td>
</tr>
<tr>
<td>TV min/day</td>
<td>-0.156</td>
<td>-0.13</td>
<td>-0.184</td>
<td>-0.157</td>
<td>-0.189</td>
<td>-0.142</td>
<td>-0.120</td>
<td>-0.093</td>
<td>-0.076</td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.119)</td>
<td>(0.032)</td>
<td>(0.071)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.10)</td>
<td>(0.310)</td>
<td>(0.407)</td>
</tr>
<tr>
<td>Video min/d</td>
<td>0.201</td>
<td>0.218</td>
<td>0.169</td>
<td>0.163</td>
<td>0.151</td>
<td>0.107</td>
<td>-0.003</td>
<td>0.052</td>
<td>0.131</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.10)</td>
<td>(0.010)</td>
<td>(0.061)</td>
<td>(0.08)</td>
<td>(0.22)</td>
<td>(0.99)</td>
<td>(0.573)</td>
<td>(0.154)</td>
</tr>
<tr>
<td>Cal/day (kcal)</td>
<td>0.09</td>
<td>0.025</td>
<td>0.009</td>
<td>0.002</td>
<td>-0.026</td>
<td>-0.048</td>
<td>0.064</td>
<td>0.007</td>
<td>-0.137</td>
</tr>
<tr>
<td></td>
<td>(0.301)</td>
<td>(0.774)</td>
<td>(0.920)</td>
<td>(0.981)</td>
<td>(0.79)</td>
<td>(0.59)</td>
<td>(0.49)</td>
<td>(0.942)</td>
<td>(0.141)</td>
</tr>
</tbody>
</table>

Pearson correlation r values are presented as well as the significance level (p-value) in brackets.
5.0 DISCUSSION

The effect of physical activity on the development of fat mass and bone mineral accrual in young childhood is relatively unknown, as there have been few studies directed at this age group. Since gymnastics training has been shown to result in an increase in the amount of time involved in physical activity and a decrease in the amount of time spent doing sedentary activities, I hypothesized that participation in gymnastics at an early age would result in a lower amount of fat mass compared to the control group. The results; however, revealed no significant differences in indices of fat mass between the gymnasts and control group.

Furthermore, there is growing evidence to support the assertion that bone mineral accrual in prepubertal children increases as a result of high-impact aerobic and strength building or weight-bearing exercise. Because of its high impact, gymnastics is an optimum sport to study the effects of mechanical loading on bone adaptation; therefore, I hypothesized that children participating in gymnastics at an early age would have higher BMC and BMD values than comparative control groups. The results; however, revealed no significant differences in indices of bone mass between gymnasts and the children in the control group. Each hypothesis is discussed separately in the context of previous literature presented. Limitations of the study as well as future directions are also discussed.

5.1 Physical Characteristics

Both the control group and the group of children participating in gymnastics were normal healthy children. There were no differences in the physical parameters measured between the two groups. Male and female controls were above the 50th percentile (CDC,
Female gymnasts were also above the 50th percentile for both height and weight at all ages. Male gymnasts were at or below the 50th percentile for height at 4 and 6 years of age and for weight at 6 years. In addition, there were no differences in the average height and weight between the two groups once age and gender were accounted for. With respect to the physical characteristics in all parameters there were no significant differences between the two groups; the gymnasts and controls were similar groups of children. This is in contrast to the studies reviewed in the gymnastics training and fat mass section, which consistently found gymnasts to be shorter and lighter than other athletic populations and controls (Laing et al, 2002; Weimann, 2002; & Zanker et al. 2003); however, the gymnasts in studies reviewed were older than the current sample. The current results may be influenced by the age as well as the training experience of the sample; this should be considered when interpreting the results of this study.

There were no differences in mothers’ height, weight, and BMI or fathers’ height, weight, and BMI between the two groups. In elite female gymnasts it has been shown that both mothers and fathers tend to be shorter than the parents of other athletic populations (Baxter-Jones, et al., 1995); again this perhaps indicates, that at this early age the potentially elite gymnasts were not differentiated from the recreational gymnasts in the current investigation. That is, the lack of height difference between the parent groups could reflect the fact that not all of children in the current gymnastics group will continue in the sport to adolescence and become elite gymnasts, when the majority of the literature with regard to gymnastics training has been obtained.
In addition, the birth weights and total energy intake of the groups were not found to be significantly different. Birth weight has been found to be related to fat mass in adolescence and young adulthood (Dietz, 1997; Pettit, et al., 1983). Although the groups responded differently over time with regard to energy intake (i.e., gymnasts had a decrease in calorie consumption between 4-5 years of age whereas the controls had an increase), there was no significant difference in the total consumption of kcal per day. If the birth weights or total energy intake had been different they would have been confounding variables had differences in fat mass been found; therefore, no differences help eliminate them as confounders.

5.2 Fat Mass

This investigation did not provide support for the hypothesis that children participating in gymnastics would have lower indices of fat mass. Gymnasts were found to have similar BMIs to that of the controls. Gymnasts were also found to have similar percentages of overweight and obese children as the control population as defined by Cole’s cut offs (Cole et al., 2000). When all the data were pooled 17.8% of the children measured were overweight and 2.5% obese. The prevalence of overweight and obese children in the current sample is less than the previously reported prevalences of 25.5% overweight and 7.1% obese in a study of slightly older Saskatchewan children (Dupuis, 2007). The high rates of overweight and obesity among these 4-6 year olds are a concern as prevalence rates tend to increase with age. The rates of overweight and obesity in this sample are similar to provincial and national averages observed in older children (Dupuis, 2007; Tremblay & Willms, 2000).
Parental obesity has been suggested as a factor affecting fat mass in children; for example, Dorosty and colleagues (2000) found that having at least one obese parent increased the risk of an earlier adiposity rebound. In the current investigation 20.5% of children who had at least one overweight parent were found to be overweight compared to 25.6% if at least one parent was obese and 27.9% if both parents were overweight or obese. Although these results suggest a familial tendency in overweight and obesity, there are also likely environmental factors, such as dietary and physical activity habits, affecting the outcome.

The lack of a group difference in indices of body fat may also be related to the homogeneity of overall physical activity of the groups, as there were no differences in physical activity scores between the groups. The control group did not participate in gymnastics; but, they were involved in other activities such as swimming, soccer, hockey, karate, etc. The NPAQ has been shown to discriminate between low and high levels of physical activity in 4-6 year old children (Saris & Binkhorst, 1977). The score on the NPAQ can range from 7-35; but, in this sample of children the average scores ranged from 22.4-26.0, suggesting that the majority children in this study had relatively high levels of physical activity compared to children observed in previous studies using the same questionnaire. Goran et al. (1997) suggested that in young children (age 5.3 ± 0.9 y) time devoted to recreational activities rather than intensity of activity may be a more important factor in maintenance of whole body energy stores (body weight); however, the average physical activity scores did not differ between individuals classified as normal weight, overweight, and obese in the current study. This is an interesting finding suggesting factors other than physical activity, alone, may be influencing fat mass
accumulation; these may include diet as well participation in sedentary activities. It is possible that the NAPQ did not capture the variation in physical activity in this sample or, conversely, it may be that physical activity is not as important in this age group.

There were no differences between the groups with regard to time spent watching TV and playing computer and video games. At this young age the amount of activity in the gymnastics classes, especially for the boys who generally train for fewer hours in childhood, may not substantially alter overall physical activity and decrease sedentary activity compared to children involved in other forms of physical activity as had been hypothesized. Goran et al. (1997) suggested that the more protective effect of lower intensity longer bouts of physical activity in young children may be a result of less time spent in sedentary activities. Because children in the preschool age group engage in free play as well as structured activities, they may habitually spend less time in sedentary activities than older children who attend school.

A main effect for age was found with regard to time spent watching TV and playing computer and video games, indicating that older children spent more time participating in sedentary activities. Therefore, as these children begin to spend more time participating in sedentary activities as they approach puberty evidence of the protective effect of physical activity and specifically gymnastics participation may become more apparent. The majority of the studies reviewed in the section on physical activity and fat mass development involved pubertal and postpubertal children (12-18 years of age) (Brekey et al., 2000 & Eisenmann et al., 2002). Since these studies were cross-sectional it is not known whether the activity levels in young childhood resulted in a cumulative preventive effect or whether those who were physically active in childhood
continued to be physically active in adolescence and young adulthood resulting in the decreased fat mass observed. However, it must also be noted that the gymnasts in the studies reviewed above were more elite than the current sample and would have self-selected into gymnastics training, in part due to their advantageous body composition.

Obesity, particularly abdominal adiposity, is associated with an increased cardiovascular risk, morbidity, and mortality in adults. Overweight 5 to 10 year old children have been found to have at least one risk factor for cardiovascular disease (Janz, et al., 2002); therefore, the current investigation explored not only total body fat mass and percent body fat, but also examined trunk (abdominal) and extremity fat. This is unique as the majority of studies examining young children simply report sum of skinfolds or use the indirect measure of waist circumference for central adiposity. The current investigation allows for the examination of the associations between physical activity and central and extremity fat mass in young children.

There were no differences between the groups for the fat variables measured by DXA including total body fat, trunk fat, and extremity fat measured in grams as well as percent body fat. Waist circumference and sum of five skinfolds were also found to be similar between the two groups. These findings do not support the hypothesis that children participating in gymnastics would have decreased fat mass. A Pearson correlation revealed that there was no relationship between BMI, waist circumference, body fat, trunk fat, and the physical activity score or the amount of time spent in sedentary activities. This finding is in contrast to the findings by Janz et al. (2002) and Moore et al. (2003) who found physical activity to be inversely related to all adipose measures in young children. Although a significant correlation was found in the current
study between TV viewing and sum of 5 skinfolds, extremity fat, and percent fat as well as physical activity and percent fat, the correlations were low. The results from the previous two studies; however, were found between children who engaged in the highest levels of daily physical activity compared to children who were the least active and watched the most TV. The lack of a physically inactive comparison group in the present study may once again be negating the effects of physical activity on fat mass measures.

Previous research has also shown that male and female adolescent and adult gymnasts have less fat mass and percent body fat compared to controls (Laing et al., 2002; Gurd & Klentrou, 2003; Weimann, 2002; Filaire & Lac, 2002). Zanker et al. (2003) examined young children (7-8 years) and determined that gymnasts had a decreased fat mass and percent body fat compared to untrained controls. The results from the current study are incongruent with the previous findings; however, the female gymnasts in the study by Zanker et al. (2003) had been systematically training for 3-4 years and trained 8-10 hours per week. In contrast, many of the female gymnasts in current study had been participating for two years and only trained two hours per week; while only eight girls trained for four hours or more per week. Even when examining the variables for the eight girls training four or more hours per week there were no significant differences in any fat variables measured when compared to the control population. The males in the study by Zanker et al. (2003) trained 4-6 hrs/week and had been involved in systematic training for 1-2 years; only one male in the current study trained for 4 hrs/week, while the majority trained for one. Thus, it is possible that the current sample had not participated in gymnastics training for a total period of time at a sufficient volume to achieve the benefits previously shown. The benefits of current training in
young childhood may not manifest themselves until later in childhood and into adolescence, when fat mass development begins to accelerate.

Although there were no significant differences between the groups at any age with regard to any fat mass variable, there were gender differences. Males had decreased total body fat, trunk fat, and extremity fat as well as a lower percent total body fat compared to females. This finding is congruent with Weimann’s (2002) finding that female gymnasts had significantly greater percent body fat than male gymnasts. Wiemann (2002) also found that gymnastics training resulted in percent fat being reduced to a greater extent in female gymnasts compared to their male counterparts. This could be a reflection of the greater number of years and increased duration of training that the female gymnasts participated in, which would indicate that with increased duration of training such changes may also be seen in the current sample of gymnasts, especially when compared to a physically inactive control population.

5.3 Bone Development

The results of this investigation did not support the second hypothesis that gymnastics training would result in increased BMC and BMD. Although Pearson correlations revealed significant positive relationships between physical activity and six of the nine bone parameters measured, the magnitude of the correlations were small. Slemenda et al. (1991) found similar size correlations in normal healthy, non-gymnast, children aged 5-14 years, total hours of weight bearing physical activity correlated significantly with bone density in the radius and upper femur. Bailey and colleagues (1999) reported that children in the highest quartile of physical activity accrued more bone and had greater BMC than children in the lowest physical activity quartile;
however, the children were older than those examined in the current investigation. It may be that there was not enough variance in the physical activity scores among the subjects in the present study to see a strong correlation with respect to bone parameters. As stated earlier, there is a possible range in NPAQ scores of 7-35; however, in this sample the lowest value was 18 and the highest 33, with the majority of scores falling between 22 and 26. This limited range of physical activity scores may mask the effect of physical activity on the bone parameters as the majority of individuals scored very high on the NPAQ.

There were no significant differences between the children participating in gymnastics and the control group in any other bone parameter as measured by DXA including: total body, spine and hip area, BMC, and BMD. Once corrected for age, height, weight and gender, there were no differences between the two groups. This finding is contrary to the numerous studies performed on the effects of gymnastics training on bone mineral accrual in adolescence and young adulthood. Studies of the effect of postpubertal gymnastics participation on bone mineral accretion have consistently demonstrated a significant positive effect. Proctor and colleagues (2002) and Fehling and colleagues (1995) found college aged gymnasts to have greater BMD compared to other athletic populations and controls. Since gymnastics training has been shown to result in increases in bone parameters in adulthood it would be intuitive to suggest that it would also produce this effect in preadolescent children when bone has been shown to be more responsive to exercise; however, this was not demonstrated in the current investigation.
Several studies support the positive effects of gymnastics training on prepubertal gymnasts. Laing et al. (2002) found that gymnasts eight to thirteen years old had greater BMD than controls. The controls used for the investigation by Laing et al. (2002) were a physically active group of similar composition to the control group in the current study. However, in the study by Laing et al. (2002) the comparison group participated in significantly fewer hours of training per week compared to the gymnasts. In the current investigation the physically active control group participated in a similar number of hours of physical activity per week and, as previously stated, did not differ on the physical activity score; therefore, the lack of increase in BMC and BMD of children participating in gymnastics compared to controls may be due to the homogeneity of physical activity levels and number of hours the control population engages in physical activity, as bone accrual in young children has been shown to be directly related to the number of hours engaged in weight bearing physical activity (Slemenda et al., 1991).

Bass et al. (1998) and Courteix et al. (1998) found gymnasts to have higher BMD at weight bearing sites compared to controls and reference values for bone. Bass et al. (1998) also found that during 12 months of training gymnasts had greater increases in BMD than the control population. Both studies used gymnasts around 10 years of age at baseline; the current investigation utilized much younger participants. The children involved in gymnastics in the current sample were not elite gymnasts and had been participating in gymnastics for a relatively short amount of time. Thus, although no differences were detected in bone mass in the current investigation, it may be that these differences will become apparent as these gymnasts age and approaches peak bone mineral accrual. This would lend support to the cumulative effect of gymnastics training
(nurture) rather than genetic predisposition (nature) which results in the increased BMD and BMC consistently seen in pubertal and postpubertal gymnasts. The gymnasts in the two studies mentioned above trained between 10 and 36 hours per week. The majority of children participating in gymnastics in the current investigation trained for one hour per week, and only eight female gymnasts and one male gymnast training for 4 hours or more per week; thus, it may be that the duration of training in the current investigation is not of a great enough magnitude to result in increases in BMC and BMD above what is achieved from other weight bearing physical activities the control cohort engaged in.

Laing et al. (2005) found two years of recreational gymnastics training to be significantly associated with greater increases in size adjusted BMD and BMC compared to a control population; however, their absolute BMC and BMD at both baseline and follow-up were actually lower than the control population. The results presented not only included the group of gymnasts training approximately one hour per week, but also a cohort training $7.89 \pm 3.05$ hrs/week. The gymnasts involved in the increased training hours per week were found to have a faster rate of accrual in the forearm than the gymnasts training fewer hours. Many of the gymnasts in the current sample had only been involved in training for one year; it may be that this is simply not long enough to see changes in bone parameters. As the children are followed over the next couple of years differences in BMC and BMD may become apparent.

It is evident that gymnasts who begin training early in life and advance to upper levels of competition have significantly greater BMC and BMD compared with other athletic populations and controls. It remains uncertain; however, if elite gymnasts are characterized by high bone mass before the onset of training or if the differences in bone
parameters result from cumulative gains with training throughout childhood and adolescence. The majority of studies to date have examined gymnasts cross-sectionally and only after they have advanced to relatively high competitive levels. Therefore, this study is unique in that it examined children in early childhood who were involved in relatively low intensity and duration of gymnastics participation before intensive systematic training has begun.

5.4 Limitations

A major limitation of the current investigation is the lack of a physically inactive comparison group. Many of the differences observed in fat mass and bone mass in previous studies of normal healthy children and gymnasts were found when comparing the highest quartile of physically active children to the lowest quartile of physical active children. Therefore, results in the current investigation may be masked by the comparatively high levels of physical activity of the control group. Another limitation of this study is the small sample. Due to difficulty recruiting gymnasts, especially older male gymnasts, some of the age groups were comprised of very few participants. The low participant numbers may also be affecting the power of the current investigation. Using my data (Table 4.3) I found that a sample size of 435 in each group would be required to have 80% power to detect a 5% difference in means of 2.15 kg of total body fat, as measured by DXA, assuming that the common standard deviation was 11.3 kg using a two group t-test with a 0.05 two-sided significance level. Similar calculations for total body bone mineral content showed a sample size of 190 in each group would be required to have 80% power to detect a 5% difference in means of 35.3 g (Table 4.5)
assuming that the common standard deviation was 122.2 g using a two group t-test with a 0.05 two-sided significance level.

Study design is also a limitation of the current investigation. Timing and tempo of growth cannot be examined in a cross-sectional study. The effect of gymnastics participation on the adiposity rebound (AR) cannot be discerned without repeated measurements; therefore, the full effect on early childhood fat mass development cannot be determined at this time. If children participating in gymnastics have a later AR it would result in subsequently less fat mass in late childhood and early adolescence. Because some of the children entering gymnastics were already overweight and obese, this is a limitation of the study, as the effects of gymnastics training may be delayed by the preexistence of increased fat mass. As a result, the effects of gymnastics training on this pediatric population may only appear with prolonged exposure to the sport. In the future, children who are classified as overweight and obese could be excluded from the cohorts to examine the effects of gymnastics on normal weight children. However, there is also a need to examine the associations between physical activity and lifestyle behaviors and the prevalences of overweight and obese children in Canada and Saskatchewan, in particular, thus this sample of children cannot be ignored.

Due to the small physique of many participants in the current study some of the hip and spine DXA scans were not able to be analyzed. Generally the scans that were not able to be analyzed were from the gymnastics group; this resulted in a smaller number of participants in this sample with bone measures of the hip and spine, which may have resulted in the lack of group differences in those measures. The choice of DXA to measure bone is also a limitation. Bone mass is only one factor affecting bone strength,
DXA does not allow for measurement of bone geometry. It may be that in these young children the geometry or architecture of the bone is what is affected by physical activity. Another limitation of the current study was the choice of questionnaire. Upon reexamination the questionnaire did not isolate gymnastics training from current levels of physical activity.

5.5 Study Strengths

Little research has been conducted examining the associations between physical activity and body composition development in young children (4-6 yrs). Four to six years of age has been identified as a critical period for fat mass accumulation and has been found to be related to both adolescent and early adult obesity. The current investigation allowed not only for the examination of the associations between physical activity and total body fat mass and percent body fat, but also, central versus extremity fat mass in young children. The majority of pervious research did not lend itself to such comparisons.

Pervious research on the effects of gymnastics training on BMC and BMD consistently site the need for studies that examine young gymnasts before systematic training has begun in order to discriminate between the effects of training and those of genetic predisposition. The current investigation explored the associations between gymnastics participation and body composition in young children. The children in the current sample would not be considered to be participating in systemic training. The current investigation revealed no significant differences in the body composition of children participating in gymnastics and the control group. Therefore, if differences appear in this sample as they begin to systematically train it would lend support to the
cumulative effect of training rather than genetics which results in the increased BMC and BMD consistently found in elite gymnasts. This would help to fill in a current gap in the literature.

5.6 Future Directions

The addition of a physically inactive control group would allow for comparison of the gymnastics group to both physically active and physically inactive control groups. The high prevalence of overweight and obese children in the current sample may also be affecting the results. Due to the low sample size it was not possible to remove these individuals from the analysis; however, future research may find a significant effect of training when these individuals are excluded.

The current sample of children needs to be followed longitudinally to elicit the effects of gymnastics training on the timing and magnitude of the adiposity rebound. Longitudinal assessment would also allow for the determination of the age at which differences in body composition from gymnastics training manifest. If gymnastics training is found to result in changes in body composition in this sample, does it also decrease the prevalence of overweight and obesity in this group? If changes in bone occur as the gymnasts age it would allow for the conclusion that gymnastics training and not genetic predisposition is responsible for the increased BMC and BMD observed in adolescent and adult gymnasts. Following these children longitudinally will answer many of questions raised in the discussion section.
6.0 SUMMARY & CONCLUSIONS

The antecedents of adult diseases such as obesity and osteoporosis have been linked to body composition development in childhood. These diseases are resulting in decreases in life expectancy and quality of life as well as dramatic rises in health care costs and, as such, are becoming a public health crisis; therefore, it is imperative to determine how, why, and when these diseases are manifesting themselves in childhood and what preventive steps can be taken. Although it has been suggested that these conditions are already apparent in the preschool population, little research has been conducted in young children (4-6 yrs). The type of physical activity as well as the duration, frequency and intensity optimal for maximal health benefits for this age group is still unknown; therefore, the current investigation examined children in early childhood to shed light on the effect of physically activity, and specifically gymnastics training, on early childhood body composition and, thus, disease prevention.

In summary participation in a gymnastics program, in the present study, at 4 to 6 years of age was not associated with body composition changes. The results suggest that as these children entered a gymnastics program their body composition was no different than their peers. In addition, no differences were found between gymnasts and children not involved in gymnastics participation in their life style behaviors as indicated by similarities in diet, physical activity and sedentary behaviors. It may be possible that engagement in gymnastics in early childhood results in benefits that do not appear until adolescence when the development of both fat and bone mass accelerates. However, benefits may also only occur if children continue to participate in gymnastics.
It is hoped that if these children were to be followed longitudinally the possible benefits of physical activity and specifically gymnastics training in early childhood could be elicited. Longitudinal studies involving young gymnasts before systematic training has begun and the long-term effects of gymnastics training are required; these will help to separate the effects of training from the effects of genetic predisposition. If gymnastics training in early childhood results in decreased fat mass and increased bone mass in adulthood then interventions can be implemented to affect population health. Future studies need to longitudinally observe young children engaged in other physical activities to identify the activities that result in the greatest long-term health benefits. Advocacy will be needed for those activities resulting in positive changes in body composition. Inventions in the preschool age group based on the research findings will then need to be implemented into primary school curriculum in order to effect population health change.
7.0 REFERENCES


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APPENDIX A: Ethics

University of Saskatchewan
Biomedical Research Ethics Board (Bio-REB)

Certificate of Approval

PRINCIPAL INVESTIGATOR
Adam Baxter-Jones

DEPARTMENT
Kinesiology

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT
College of Kinesiology
105 Gymnasium Place
Saskatoon SK S7N 5C2

STUDENT RESEARCHER(S)
Marta Erlanson

SPONSORING AGENCIES
UNIVERSITY OF SASKATCHEWAN

TITLE:
The Effects of Structured Early Childhood Physical Activity of Childhood Body Composition

ORIGINAL APPROVAL DATE
12-Jul-2006

CURRENT EXPIRY DATE
01-Jul-2007

APPROVAL OF
Revised Researcher's Summary Form
Appendix A -- Revised Research Participant Information and Consent Form
Appendix B -- Recruitment Advertisement/Poster
Appendix C -- Food Frequency Questionnaire
Appendix D -- Parent Survey, Parts I and II

CERTIFICATION
The University of Saskatchewan Biomedical Research Ethics Board has reviewed the above-named research project at a full-board meeting (any research classified as minimal risk is reviewed through the expedited review process). The proposal was 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 governing law. This Approval is valid for the above time period provided there is no change in experimental protocol or in the consent process.

ONGOING REVIEW REQUIREMENTS/REB ATTESTATION
In order to receive annual renewal, a status report must be submitted to the Chair for Committee 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/ethics.shtml. In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

APPROVED.

Michel Desautels, Ph.D., Chair
University of Saskatchewan
Biomedical Research Ethics Board

Please send all correspondence to:

Ethics Office
University of Saskatchewan
Room 305 Kirk Hall, 117 Science Place
Saskatoon, SK S7N 5C8
Phone: (306) 966-4053 Fax: (306) 966-2069

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APPENDIX B: Recruitment Poster

Participants Needed:

For a Study on the Effects of Gymnastics Training on Early Childhood Body Composition

We are looking for children 4 to 6 years of age for a research study on the effects of gymnastics training on the development of fat, bone and lean tissue in young children. It will involve measures of height, weight, fat and bone mass as well as assessments of dietary and physical activity patterns.

This Study is being conducted through the College of Kinesiology at the University of Saskatchewan.

The time commitment will be between 20 minutes - 1 hour depending on level of participation.

For further information please contact Marta Erlandson, Graduate Student, College of Kinesiology at 966-1123, marta.erlandson@usask.ca or Dr. Adam Baxter-Jones, Associate Professor, College of Kinesiology at 966-1078 or baxter.jones@usask.ca
Title:
The Effects of Structured Early Childhood Physical Activity on Childhood Body Composition

Investigators:
Adam Baxter-Jones, Ph.D., Associate Professor College of Kinesiology, 966-1078
Marta Erlandson, BSc. Kin., Student Researcher College of Kinesiology, 966-1123

Introduction:
Your child is invited to participate in a study entitled The Effects of Structured Early Childhood Physical Activity on Childhood Body Composition. His/her participation in this study is entirely voluntary and he/she may withdraw at any time without penalty. Before you decide to allow your child to participate it is important that you understand what the research involves. This consent form will tell you about the study, why the research is being done, and your child’s role as a volunteer along with the possible benefits, risks and discomforts involved. If you decide to allow your child to participate you will be required to sign this consent form. Please read this form carefully and feel free to ask any question you might have.

Purpose:
The purpose of this study is to determine the effect of structured early childhood physical activity on the body of composition (fat, lean, and bone tissue). Childhood and adolescence are the only two times in life when an individual increases the number of fat cells in their body. Data exists looking at the effects that physical activity has on fat, lean and bone tissue in children from 7 years to adult; however, little exists looking at children under the age of 7.

Procedures:
With your child’s participation, you will be required to complete questionnaires regarding your child’s personal information (such as name, telephone number, birth weight etc.), general health and medical history, as well as their physical activity and dietary patterns. You will also be required to fill out a questionnaire regarding why or why not you chose for your child to be involved in sport and recreation. Your child’s participation in this project will involve a measure of height, sitting height and weight.

If your child is randomly selected to the sub-sample he/she will also have their body composition assessed by DXA (dual energy x-ray absorptiometry). DXA is a scan that is done while your child lies on their back on what looks like an x-ray table, it assess fat, bone and lean tissue. The scan will take approximately 20 minutes to complete and will expose your child to a minimal amount of radiation. The total radiation per session is less than 10 millirem (mrem) which is similar to the background radiation one would...
receive making a return flight from Saskatoon to Halifax on a commercial airline. For comparison purposes, the average annual background radiation in Saskatoon due to natural sources is approximately 150 mrem and the current permissible dose for the general population is 500 mrem per year. The typical exposure from a routine dental x-ray is over 50 mrem. These values can be used to compare the relative risk of the less than 10 mrem exposure from the bone density procedure. All DXA scans will be administered by certified technologists.

Children selected into the sub-sample will also be required to wear an Actical accelerometer for 7 consecutive days. The accelerometer is a type of motion sensor that measures accelerations and decelerations of movement. The accelerometer will be attached to a belt around your child’s waist. You will be required to put the Actical on your child as soon as possible after waking in the morning and your child will need to leave it on until bedtime, expect when swimming or bathing.

Potential Benefits:
The benefits of participating in this experiment include an increased knowledge of your child’s overall health status, including fat mass, lean mass, bone density and activity and dietary patterns. There is no guarantee that the participant will receive any direct benefit from the study.

Potential Risks:
The minor risks of this experiment involve exposure to small amounts of radiation during DXA analysis of bone density. If you allow your child to participate, it is assumed that you understand these risks and consider them acceptable.

Research-Related Injury:
There will be no cost to you for your child’s participation in this study. You will not be charged for any research procedures. In the event that your child becomes ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights.

Alternative Procedures or Course of Treatment:
Your child does not have to participate in this study to have their body composition assessed. These tests can be arranged through appointment in the College of Kinesiology.

New Finding:
If, during the course of this study, new information becomes available that may related to your willingness to allow your child to continue to participate, this information will be provided to you by the investigators.

Data Storage:
All data will be recorded on password protected digital media and stored in a locked office at the University of Saskatchewan for a minimum of five years in the growth and
development laboratory. All participant data will be coded with subject number at time of collection. Only the researcher and the research assistants will have access to the data.

**Right to Withdraw:**
It is understood that your child will be free to withdraw from any or all parts of the study at any time without penalty.

**Confidentiality:**
Your child’s identity will remain confidential and only those directly involved in the study (that is the investigator and research assistants) will have access to his/her records and results. All individual results will remain strictly confidential.

**Questions:**
Please be assured that you and your child may ask any question at any time. We will be glad to discuss your child’s results with you and your child when they become available and we welcome your comments and suggestions. Should you have any concerns about this study or wish further information please contact:
- Marta Erlandson (phone: 966-1123, email: marta.erlandson@mail.usask.ca)
- Dr. Adam Baxter-Jones (phone: 966-1078, email Baxter.jones@usask.ca)

The Biomedical Ethics Committee has approved this study on ethical ground on . Any questions regarding your child’s rights as a participant may be addressed to the Ethics Office of the Vice President Research (966-2975).
**Consent:**
I understand the purpose and procedures of this study, as described, and I voluntarily agree to allow my child to participate. I understand that at any time during the study, my child will be free to withdraw without penalty. I understand the contents of the consent form.

I have had the opportunity to ask questions and have received satisfactory answers to all inquires regarding this study.

A copy of this consent form has been given to me for my records.

________________________________________   _____________
Signature of Parent     Date

________________________________________   _____________
Signature of Investigator    Date

________________________________________   _____________
Verbal Assent from Child     Date
APPENDIX D – The Netherlands Physical Activity Questionnaire

Instructions: Please circle the number that best describes your child during the past six months. For example, if in the past six months, your child preferred to play alone as often as he/she preferred to play with other children, circle the number three for the first question. On the other hand, if he or she almost always preferred playing with other children, rather than alone, circle the number five.

<table>
<thead>
<tr>
<th></th>
<th>Almost Always</th>
<th>About Equal</th>
<th>Almost Always</th>
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</thead>
<tbody>
<tr>
<td>1. Prefers to play alone</td>
<td>1 2 3 4 5</td>
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<tr>
<td>2. Prefers vigorous games (e.g., tag, kickball)</td>
<td>1 2 3 4 5</td>
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<tr>
<td>3. Dislikes playing sports (e.g., soccer, basketball)</td>
<td>1 2 3 4 5</td>
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<td>4. Is more introverted (e.g., quiet, reserved)</td>
<td>1 2 3 4 5</td>
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<tr>
<td>5. Likes to read</td>
<td>1 2 3 4 5</td>
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<tr>
<td>6. Likes to play outside</td>
<td>1 2 3 4 5</td>
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<tr>
<td>7. Less physically active compared to other children of same age</td>
<td>1 2 3 4 5</td>
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</tbody>
</table>

Instructions: Please answer the following questions as they relate to your child's usual daily routine during the past six months. Estimate the time to the nearest 1/4 hour (15 minutes) per day.

8. On average, how many hours per day does your child spend watching any type of television including video movies?

   ____________________________ hours per day

9. On average, how many hours per day does your child spend playing video games (such as Nintendo®) and/or computer games?

   ____________________________ hours per day
10. On average, how many hours per night does your child spend sleeping? (Do not include naps.)

__________________________ hours per night

11. On average, how many hours per day does your child sleep during naps?

__________________________ hours per day

Please list the two play- or sport-related physical activities which your child did most often during the past six months (e.g., kickball, board games, biking, soccer, puzzles, playing on playground equipment, roller blading, swimming, rope jumping):

12. ____________________________  13. ____________________________

14. During the past six months, did your child participate in or take lessons in any of the following organized sports? (Check all that apply.)

- ______ Swim lessons/swim club
- ______ Youth soccer
- ______ Basketball league/camp
- ______ T-ball/baseball/softball
- ______ Gymnastics/tumbling
- ______ Dance/ballet/jazz/aerobic
- ______ Hockey/ice/roller/indoor
- ______ Tennis/racquetball
- ______ Track & field/running
- ______ Football league/camp
- ______ Horseback riding
- ______ Volleyball league/camp

- ______ None

Others (Please list.) ____________________________

15. When in school, how often does your child participate in physical education (PE)?

- ______ daily
- ______ 2-4 times/week
- ______ once/week
- ______ does not participate
- ______ don’t know

16. What arm does your child prefer to throw with?

- ______ right
- ______ left
- ______ no preference
- ______ don’t know

17. What leg does your child prefer to kick with?

- ______ right
- ______ left
- ______ no preference
- ______ don’t know

Thank you for taking the time to complete this physical activity questionnaire.
APPENDIX E – 24 Hour Dietary Recall

UNIVERSITY OF SASKATCHEWAN
24-HOUR RECALL

Please list every food and drink your child had yesterday.

Name: __________________________ Age: ______________ Date: ____________

<table>
<thead>
<tr>
<th>Time</th>
<th>Food Item</th>
<th>Type &amp; Preparation</th>
<th>Amount</th>
<th>Brand Name or Where Bough</th>
</tr>
</thead>
<tbody>
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<td>Morning</td>
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<td>Mid-morning</td>
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<td>Noon Meal</td>
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<td>Midday</td>
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<td>Evening Meal</td>
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<td>Before Bed</td>
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Example: Cereal: Corn Flakes: 1 cup: Kelloggs
          Milk: 1%: ½ cup: Dairy Land

Was this intake usual? Please circle one: Yes  No (if no please explain: ____________ )