EXAMINING THE POTENTIAL APPLICATION OF CHILDHOOD STATURE IN ASSESSING ADOLESCENT OVERWEIGHT AND OBESITY

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Abstract

Background: Increasing Overweight and Obesity (OwOb) prevalence in pediatric populations is becoming a public health concern in many countries. The purpose of this study was to determine if childhood stature components, particularly the Leg Length Index (LLI = [height – sitting height]/ height), were useful in assessing risk of OwOb in adolescence.

Methods: Data was from a longitudinal study conducted in south Ontario since 2004. Approximately 2360 students had body composition measurements including sitting height and standing height at baseline. Among them, 1167 children (573 girls, 594 boys) who had weight and height measured at the 5th year follow-up, were included in this analysis. OwOb was defined using age and sex specific BMI (kg/m^2) cut-off points corresponding to adults' BMI $\geq$ 25.

Results: Overall, 34% (n=298) of adolescents were considered as OwOb. The results from logistic regression analysis indicated that with 1 unit increase in LLI the odds of OwOb decreased 24% (Odds Ratio, [95% Confidence Interval], 0.76, [0.66-0.87]) after adjusted for age, sex and baseline waist circumference. Further adjusting for birth weight, birth order, breastfeeding, child's physical activity, maternal smoking, education, mother's age at birth and mother's BMI, did not change the relationship. Our results also indicated that mother's smoking status is associated with LLI.

Discussion: Although LLI measured at childhood in this study is related to OwOb risk in adolescents, the underlying mechanism is unclear and further study is needed.

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List of Abbreviations

AR: Adiposity rebound period

BMI: Body mass index

CHD: Coronary heart disease

CIHR: Canadian Institutes of Health Research

CVD: Cardiovascular disease

DCD: Developmental coordination disorder

ELE: Early Life Experience

FEAQ: Family Eating and Activity Habits

FOH: Fetal origin hypothesis

HC: Hip circumference

LLI: Leg length index

OGS: Optimal growth study

OwOb: Overweight and obesity

PA: Physical activity

PHAST: Physical Health Activity Study Team

PQ: Participation Questionnaire

SSHRC: Social Sciences and Humanities Research Council of Canada

SES: Socioeconomic status

SHI: Sitting height index

SS: Smoking status

T: Tertiles

WC: Waist circumference

CHAPTER 1: INTRODUCTION

Overweight and obesity (OwOb) in childhood and adulthood has been identified as a major public health concern in developed nations. This is attributed to the many adverse conditions associated with the disease and its markedly increasing prevalence over the last quarter of the century. In Canada, adult OwOb prevalence rates have increased dramatically from 14% in 1979 to over 59% (overweight: 36%; obese: 23%) in 2006 (Statistics Canada, 2006). Within the same time frame, childhood overweight prevalence climbed significantly to 18% while obesity rates more than doubled to 8% (Statistics Canada, 2005).

Increased body adiposity in pediatric populations is of particular concern because children suffering from OwOb are more likely to encounter issues with their cardiovascular health, endocrine system, mental health and sexual maturation than their normal weight counterparts (Mamun, Hayatbakhsh, O'Callaghan, Williams, & Najman, 2009). Additionally, OwOb can cause and complicate many other health conditions ranging from pulmonary, orthopedic, gastrointestinal to hepatic problems (American Academy of Pediatrics, 2002; Rashid & Roberts, 2000). Furthermore, OwOb children tend to remain OwOb in adolescence and adulthood. In fact, the probability of childhood obesity persisting into adulthood increases from approximately 20% at four years of age to 80% by adolescence (Chumlea & Guo, 1999). Consequently, childhood comorbid conditions will also persist into adulthood. Notwithstanding the fact that increased adiposity in adulthood has been linked to its own exhaustive list of diseases including; cardiovascular disease (CVD), cancers, type 2 diabetes, hypertension, liver disease, stroke, sleep apnea, osteoarthritis, gallbladder disease, depression and other chronic diseases (Must, Jacques, Dallal, Bajema & Dietz, 1992; Wisemandle, Maynard, Guo & Siervogel, 2000).

It is certain that increased adiposity in childhood and adolescence is an important predecessor to adverse health effects in later life. Focusing on its control is therefore of utmost importance in order to avoid compromised future health risk of both children and adults. The most efficient and ideal way to target this problem is to implement a preventative approach focused on risk assessment early in a child's life, prior to OwOb development.

The current study examined childhood stature components (i.e. standing height, sitting height, leg length, leg length index [LLI] [leg length/standing height *100]) in assessing future adiposity risk. As markers of childhood growth and development, stature components have shown significant OwOb and other chronic disease predictive potential in adult populations. In pediatrics however, the relationship is understudied and thus not as apparent.

The purpose of this study, therefore, was to identify if stature, specifically in relation to the LLI, had pediatric OwOb predictive properties while controlling for important confounders that could modify the child's future disease risk. This was assessed through examining stature in childhood, after the child's critical growth period (pre-pubertal age 9-11 years), with development of OwOb in adolescence (pubertal age 13-14 years). Hypothetically, if significant associations were displayed, childhood stature could possess valuable potential as a pediatric OwOb identification tool.

CHAPTER 2: LITERATURE REVIEW

Adiposity and Cardiovascular Disease (Adults)

The adverse effect of overweight and obesity on cardiovascular disease risk has been well documented over the past 30 years. It was first observed from analyses of the Framingham Heart Study, a 36 year longitudinal study of the precursors of cardiovascular disease in 5,209 adults between the ages of 28 and 62 years from Framingham, Massachusetts. After 26 years of follow-up, Hubert et al (1983) concluded that obesity was a significant independent predictor of CVD, including coronary heart disease (CHD), coronary death and congestive heart failure in both men and women after adjustment for risk factors. Many analyses of population longitudinal data and animal data over the last quarter of the century have arrived at the same conclusions. It is evident that increased body adiposity has a major impact on the risk of cardiovascular diseases such as angina, myocardial infarction, CHD and stroke and is associated with reduced overall survival in both men and women (Poirier et al., 2006).

Adiposity and Cardiovascular Disease (Children)

Recent studies have noticed CVD risk accruing quickly in children, well before adulthood; one of the largest culprits for this being increased body adiposity in childhood. OwOb has devastating effects on a child's health while concomitantly increasing their sensitivity to disease in adulthood. It has been shown to have significant short-term effects on the child's cardiovascular system, including impaired endothelial function, diminished arterial distensibility, adverse changes in intimamedia thickness and increased risk of atherosclerosis (Whincup & Deanfield, 2005). These factors all increase the child's risk of metabolic syndrome and consequent adulthood CVD. In fact a new study has found that obese children as young as 7 years of age may have an increased risk of future heart disease and stroke, even without the presence of other cardiovascular risk factors (The Endocrine Society, 2009). Furthermore, OwOb children are likely to become overweight or obese adults and thus are at risk for all the diseases associated with adulthood OwOb.

Evidently there is a very strong and alarming association between body adiposity and CVD in both children and adults as documented by countless studies. OwOb is a modifiable culprit in CVD risk and needs to be targeted effectively by preventative measures.

Stature-Disease Associations (Adult)

Many studies have observed significant associations between stature components and future disease risk and mortality in adulthood. Stature has been inversely related to respiratory disease (Leon et al., 1995) and metabolic disease (Asao et al. 2006), while associations with cancers have been inconsistent (Jousilahti et al., 2000, Davey Smith et al., 2000). Strong and consistent relationships are well documented with OwOb and CVD.

Stature and Adiposity. Several studies have established associations between short stature in adulthood and risk of obesity. Asao et al. (2006) found that the body fat percentage was significantly higher in women with shorter height, shorter leg length, and lower leg length index even after controlling for factors known to influence body fat. A similar pattern was noted in men. Other studies also found inverse associations between the risk of OwOb and leg length index in middle-aged adults (Davey Smith et al., 2001; Gunnell et al., 2003). Studies generally agreed on stature's important disease predictive properties in assessing development of adult OwOb.

Stature and Cardiovascular Disease. A number of epidemiological studies done on men and women have found striking inverse relations between adult height, cardiovascular disease incidence, and mortality. In general, these cohort studies have shown that greater stature is associated with longevity; specifically, cardiovascular mortality decreases with increasing stature and this association persists even after controlling for potential confounders (Hebert et al., 1993; Kannam et al., 1994; Parker et al., 1998; Rich-Edwards et al., 1995; Yarnell et al., 1992). However, these studies have been criticized of important limitations such as small sample sizes, and using cross-sectional data without adjusting for important risk factors (i.e., child's nutrition, body fat distribution, lung function). Nevertheless, the association between stature and CVD disease is an obvious and important one in which stature has shown significant associations with risk of adulthood CVD.

Stature-Disease Associations (Children)

Of significance is whether stature has similar attributes in the pediatric population. Considering stature's potential in adult risk assessment, it is plausible that it functions similarly in children. However, research investigating stature and disease associations among children is limited. One recent study specifically focuses on pediatric stature and OwOb development. Interestingly it authenticates promising results for stature's potential as a simple, albeit important, early childhood OwOb identification tool; however it calls for longitudinal data confirmation (Pliakas & McCarthy, 2009).

The lack of longitudinal in-depth research can be attributed to the relatively low prevalence of childhood chronic disease in previous years. Lower OwOb prevalence hindered direct assessment of the childhood stature-childhood OwOb association. Furthermore, studying adult OwOb and CVD was of higher priority since it was significantly more prevalent and associated with disease mortalities and morbidities. At present however, higher prevalence of OwOb in child and adolescent populations has made studying and identifying preventative methods extremely important. Additionally the increased OwOb prevalence provides ample subjects for stature-OwOb research focus. Identified childhood OwOb can further be used as a proxy indicator of future cardiovascular risk (i.e., hypertension, type 2 diabetes etc.) since those who are at risk of child and adolescent OwOb are likely to develop adulthood OwOb and subsequent health-related consequences. Moreover studies have identified the child's pre-pubertal critical growth period (also known as the adiposity rebound [AR]; age 4-8 years), as an effective time in a child's development to initiate detection of and prevention for early onset of OwOb (Wisemandle et al., 2000). As the early stage of childhood development where increased adiposity is generally initiated, the AR is a key timeframe in obesity prevention. Therefore assessing statures potential as a preventative screening method in this timeframe is ideal and should be very efficient.

However it is important to note while there are many components to stature not all have the important predictive qualities. The component that contributes most to the observed associations is leg length.

Stature: Leg Length

Leg length is the component of stature responsible for rapid growth during childhood and adolescence (Krogman, 1972; Scammon, 2005; Tanner, 1978). As such, it can be used as an important indicator of pre-pubertal growth. This is evident in both longitudinal and cross-sectional anthropometric data (Gunnell et al., 1998; Gunnell, Davey Smith, Holly & Frankel, 1998). Displayed in Figure 1 are leg length and sitting height growth curves for both males and females between the ages of 2 and 20 years. Leg length and sitting hight are portrayed as indexes relative to overall height: Leg Length Index and Sitting Height Index (SHI) = (sitting height/standing height*100). Frisancho (1997) used these graphs to illustrate that leg length in childhood and adolescence grows very rapidly (top graph: steep incline from 2-12 years) and contributes more to the variability in stature than sitting height (most of them from the trunk length) which grows very slowly (bottom graph: steep decline from 2-12 years).

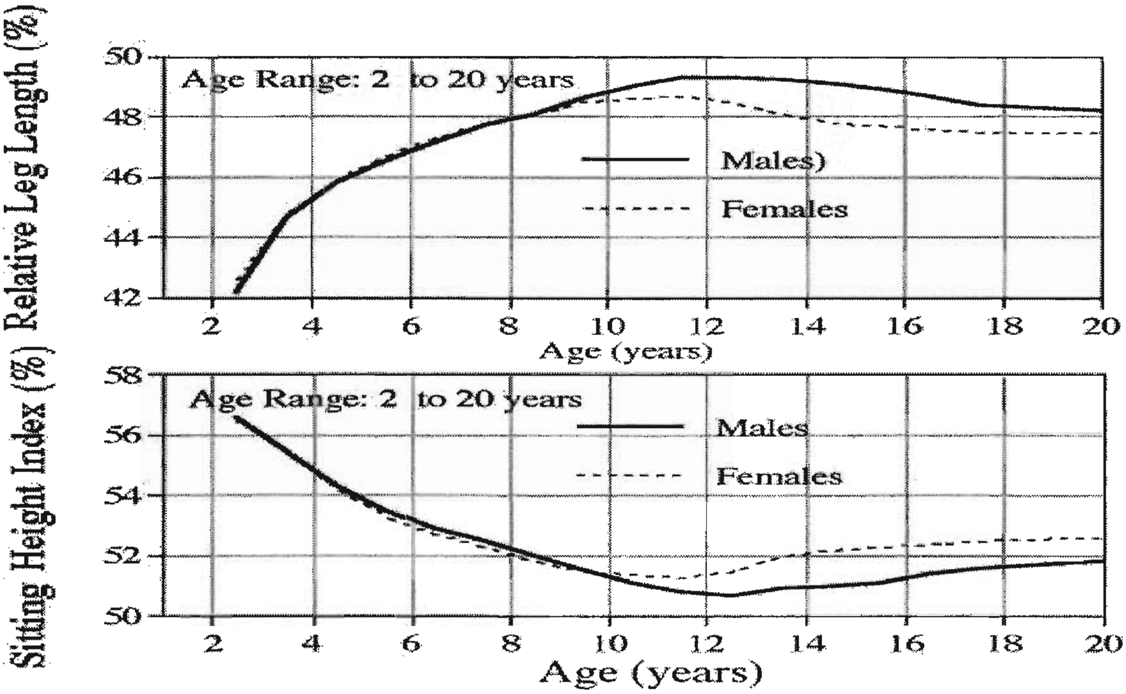


Figure 1: Relative growth of leg length and sitting height [Adapted from Frisancho, 2007].

Therefore leg growth, as opposed to trunk growth, is most sensitive to social and environmental factors during early childhood. The nature of these factors contributes to the child's risk of OwOb, CHD, mortality and insulin resistance (Gunnell, 1998a; Gunnell, 1998b; Smith et al., 2001). Positive factors enhance growth and development thereby contributing to longer leg length and decreased risk of future disease. Negative influences have the opposite effect.

Among both sexes, risk of adulthood CHD has been most strongly related to leg length than any other stature component (Davey Smith et al., 2001; Gunnell et al., 2003; Lawlor et al., 2004). Smith et al. (2001), using age-adjusted analyses of middle-aged men in the Caerphilly study, found that leg length, but not height or trunk length, was associated with incident CHD events (Davey

Smith et al., 2001). Likewise, Ferrie et al. (2006) in an analysis of the Whitehall II Study of British Civil Servants found that leg length tended to be more strongly associated with CHD risk factors in both women and men. Also, trunk length appeared to be more closely associated with non-fatal coronary events than either leg length or overall height (Ferrie, Langenberg, Shipley & Marmot, 2006).

Evidently most studies concur that the component of stature most closely associated with disease risk is leg length. Since the majority of pre-pubertal overall height increase is due to leg growth (whereas pubertal height growth is due to trunk growth) (Buckler, Kelnar, Stirling & Saenger, 1998), leg length is the component of stature most sensitive to environmental influences in the critical AR growth period (Gunnell, Davey Smith, Frankel, Kemp & Peters, 1998). As such, it can potentially serve as an indicator of social, environmental and nutritional status in pre-pubertal childhood (age 4-8 years) (Gunnell, 2001).

In order to efficiently examine leg length's disease association, some studies have suggested use of the leg length index (LLI). The LLI is a ratio of leg growth relative to overall growth (leg length/ standing height *100). Studies suggest it provides a more accurate depiction of leg growth since it is adjusted for any variability that can be caused by trunk growth.

Stature: Leg Length Index

A few studies that have looked at the utilization of LLI as a predictor of future OwOb and CVD have shown promising results. Asao et al (2006) investigated the use of LLI, sitting height, standing height and leg length in identifying risks of adiposity, insulin resistance, and type 2 diabetes in an adult cohort. The same study concluded that although lower overall height, leg length and LLI were all associated with higher prevalence of diabetes, only the LLI was also associated with greater levels of insulin resistance in subjects without diabetes. In fact, a 1-standard deviation lower LLI was associated with a 19% greater risk of having type 2 diabetes, whereas leg length and overall height did not show similar strong associations.

Pliakas & McCarthy (2009) reported similar results among a pediatric sample aged 5-15 years. These researchers analyzed the association between body adiposity, leg length, trunk length and LLI cross-sectionally. Results showed that LLI had strongest associations with risk of OwOb, than any other stature component. OwOb children also had relatively shorter LLI than normal weight children across most ages. Pliakas & McCarthy suggest significant associations between LLI and body fat in children, however call for longitudinal data confirmation.

Frisancho (2007) investigated many stature components including trunk length, leg length, standing height, LLI and SHI and noted strongest associations between LLI and higher percent body fat. Frisancho provided an interesting explanation for his observations suggesting that a low LLI is a biological indicator of negative environmental factors during prenatal and early childhood development. The negative factors result in delayed growth which subsequently leads to an increased risk of CVD and obesity. On the other hand, a high LLI is an indicator of positive environmental factors during development resulting in advanced growth and decreased risk (Frisancho, 2007). Given that LLI is calculated from leg length, their associations with risk of OwOb are explained similarly. There are several proposed theories that attempt to further explain the observed phenomenon.

Explanation for Stature-Disease Associations

Many new and old hypotheses have attempted to explain the stature-disease association. The most important explanations include Barker's Fetal Origins Hypothesis (FOH) which focuses on prenatal metabolism programming, Lietch's early life exposures hypotheses and Karsenty's explanation of bones metabolic potential.

Barker: Fetal Origin Hypothesis. An interesting explanation for the stature and CVD association was put forth by Barker (1998) who looked at maternal and fetal nutrition and its affect on disease risk in later life. Barker's FOH suggests that a fetus' metabolism may be permanently changed by levels of prenatal nutrition. He explains that poor inutero nutrition and hormones may affect the structure and function of β-cells in the adult pancreas. This can lead to adaptations made by the fetus (i.e. slowing of body growth and development) which permanently change the structure and function of the body. Barker identifies four body phenotypes: thin, short, short and fat, and large placenta, which can increase the fetus' later risk of insulin resistance, cardiovascular disease and non-insulin dependent diabetes (Barker, 1995). This hypothesis suggests that a child's disease risk can begin to accrue well before the child's birth, and hence the contribution of intrauterine growth is vital to later disease development. Although Barker's hypothesis provides a plausible explanation for observed stature-disease associations, it only takes into account prenatal exposures. Early life postnatal exposures are also vital to the study of stature and disease.

Lietch: Early Life Exposures. The effects of postnatal environmental influences was first observed by Lietch (1951) who explained that many nutritional, social, and other environmental factors in early life significantly affect a child's body development and growth. Furthermore, the child's height could be used as a marker of those early life conditions. Leitch explains that the interruption of body growth at any stage results in a relatively long torso and short legs (Leitch, 1951; Mitchell, 1962) and if the rate of growth is sufficiently slowed down by negative growth conditions, the adult will have relatively short legs. Alternatively, a relatively long leg would imply rapid growth and the influence of positive environmental factors during childhood and adolescence.

Lietch's observations led many studies to investigate the effect of postnatal early life experiences on CVD development later in life. As suspected, these studies found that early life factors including socioeconomic status, parental smoking, child's nutrition (i.e. breastfeeding) and physical activity could also affect the child's risk of disease in adulthood. More importantly, the studies concluded that although stature is not directly related, it can be used as an indirect marker of this risk. This is a plausible explanation and was widely accepted until recent research identified an actual metabolic role of bone.

Karsenty: Bone's Metabolic Role. The metabolic potential of bone was first observed by Ducy et al (2000) who hypothesized of adiposity's protective effect on mammalian osteoporosis. Ducy suggested the possibility of bone remodeling and energy metabolism to be regulated through feedback regulation by the same hormones that are involved in the protective effect. Dr. Gerard Karsenty and colleagues (2006) further investigated this hypothesis by researching the effects of leptin (an adipocyte-derived hormone known to regulate energy metabolism). Karsenty found that leptin was a major regulator of bone remodeling by acting on osteoblasts through two separate neural pathways (Karsenty, 2006). These results led Karsenty to suspect that if bone cells could determine the level of activity of hormone-producing cells, then osteoblasts should affect energy metabolism. Accordingly, Karsenty et al. (2007) made the groundbreaking discovery that bone (through osteoblast activity) plays a powerful role in the regulation of blood sugar and fat deposits. It was found that mice with an inactivated osteoblast gene called *Esp*, which encodes for a receptor-like protein tyrosine phosphatase called OST-PTP, were hypoglycemic and protected from obesity and type 2 diabetes by having increased beta-cell proliferation, and an increase in both insulin secretion and insulin sensitivity. The investigators identified osteocalcin (a protein secreted by osteoblasts) as the principal hormone responsible for the metabolic effects seen in the *Esp*-deficient mice whereby inactivation of the *Esp* gene increased the metabolic bioactivity of osteocalcin. Researchers observed that deleting even a single allele of the gene encoding for osteocalcin reversed the beta-cell proliferation, insulin secretion and insulin sensitivity effects. Furthermore, deletion of both alleles resulted in mice that were both glucose intolerant and obese (Lee et al., 2007). Karsenty concluded that mice with genetic inactivation of *Esp* have increased osteocalcin hormonal activity and thus have many metabolically desirable characteristics including increased proliferation of pancreatic beta cells, increased insulin secretion, lower blood sugar, increased insulin sensitivity, decreased visceral fat, and increased energy expenditure (Figure 2).

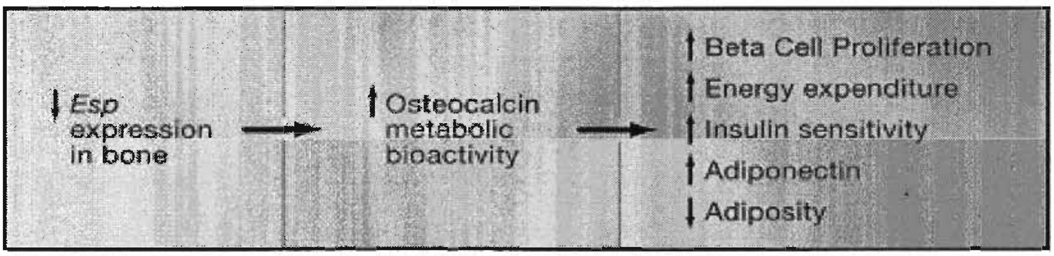


Figure 2: Effects of Bone on Energy Metabolism. [Adapted from Semenkovich and Teitelbaum, 2007]

This groundbreaking discovery provides new evidence for why increased stature has a protective effect on CVD and obesity development. It suggests that bone actually plays a hormone regulatory role which can directly affect disease risk (i.e. increased stature implies longer bones and hence more osteoblast and osteocalcin activity). This further explains why any factor that results in decreased stature (i.e. decreased growth and development of bone) such as poor nutrition, low SES and parental smoking will significantly increase the risk of CVD and obesity. Specifically factors that affect important stature growth periods in childhood have greatest influence of growth and development. These factors must be accounted for in order to visualize an accurate association between stature and OwOb.

Stature: Modifying factors

Several variables can affect a child's growth and development and consequent risk of disease. These include, but are not limited to, prenatal factors (child's birth weight, birth order, mother's pregnancy smoking status, and mother's age at child birth), genetic factors (parental height and BMI) and postnatal factors (breastfeeding, child's physical activity and SES) (Gigante, Horta, Lima, Barros, & Victoria, 2006). In order to accurately assess the relationship between stature and disease risk, these variables must be adjusted as confounders since they may account for the observed association.

Pre-Natal Factors

Child's birth weight. A baby's birth weight has shown to be an indicator of future disease risk in many studies. In general, factors that result in the child having a reduced birth weight such as poor maternal nutrition and smoking, can lead to an insulin-resistant genotype that results in glucose intolerance, insulin resistance, diabetes, CVD, OwOb and hypertension (Ferrie et al., 2006; Hattersley & Tooke, 1999). Reversely, increased birth weight provides protective effects against these chronic conditions. It is therefore necessary to adjust for birth weight when assessing the association between stature and disease development as it could be a confounder.

Maternal smoking. A mother's smoking during or post-pregnancy has a known effect on the child's birth weight. Newborns of smoking mothers tend to have relatively lower birth weight and shorter legs in comparison to their non-smoking counterparts (Gigante et al., 2006; Lawlor et al., 2004). As previously mentioned, a lower birth weight increases the child's risk of CVD and obesity in adulthood. Therefore, smoking must also be adjusted for as a confounder.

Birth order. Many studies have concluded that a child's health outcome can be determined by where the child falls in the family birth order. The most common finding is that children with higher birth orders have less favorable outcomes (Hatton & Martin, 2008). More specifically, studies indicate that birth order and the number of children both have adverse effects on height (Gunnell et al., 1998c; Li & Power, 2004). Children born later (e.g. higher birth order) have shorter stature and a higher risk of disease. As such, birth order needs to be adjusted for as a confounder.

Maternal age at child birth. Several studies have shown that the risk of type 1 diabetes increases with a high maternal age at child birth (Bingley et al., 2000; Blom et al., 1989; Metcalfe & Baum, 1992). This association may be mediated through the child's stature. Older mothers have a higher risk of having lower birth weight children who will have relatively shorter stature. Low birth weight is major risk factor for many childhood diseases including diabetes. Although the current study does not assess development of type 1 diabetes, as diabetes is related to obesity and other CVD, maternal age might actually play a confounding part in the association between LLI and obesity. Therefore, it is valuable to adjust for this variable.

Genetic factors· As many studies have reported, the factors that regulate adult stature are multidimensional. Although environmental and metabolic factors are important in the regulation of growth and development in childhood, they contribute to less than 20% of the variability in adult stature (Palmert & Hirschhorn, 2003). Results from adult family and twin studies suggest that it is actually genetics that play a major role in determining stature. In fact, studies conclude that the fraction of variation in height explained by genetics ranges from 76-90%, with most studies giving proportions above 80% (Jepson et al., 1994; Palmert & Hirschhorn, 2003). Genome-wide association studies have identified more than 30 chromosomal sites and potential genes that appear to be partially involved in the regulation of adult stature in humans (Lettre et al., 2008; Weedon et al., 2008). However, the specific effects of these genes on stature still remain vaguely defined. Due to this ambiguity, many studies focus on the more measurable, modifiable factors that may explain the other 20% of variation in stature. Favorably our study encompasses valuable parental height and BMI data that will be used as a reference for the child's genetic predisposition. The contribution of genetics to the child's stature and risk of OwOb will be accounted for by using maternal height and maternal BMI respectively.

Post-Natal Factors

Breastfeeding. Receiving proper and adequate early life nutrition (indexed by breastfeeding) has a profound effect on the stature-disease association. Being breastfed and a higher energy intake at 4 years of age have been associated with longer leg length in adulthood. Not surprisingly, being breastfed is always related to lower long-term risk of obesity and type 2 diabetes (Asao et al., 2006). Thus breastfeeding also needs to be adjusted for in the analysis.

Socioeconomic Status. Literature indicates that short stature in adults is associated with poorer educational status and lower socioeconomic level (Gigante et al., 2006). These statuses are primarily from family background, but other environmental factors in childhood may also play a role (Silventoinen, 2003). Some studies have suggested that the association between CVD risk and height may be confounded by childhood and adulthood socioeconomic conditions since favorable socioeconomic circumstances are related to greater stature. However, this is only partially the case since associations between stature and CVD risk persist after adjustment for both childhood and adulthood SES (Davey Smith, 2000; Davey Smith, Shipley & Rose 1990; Notkola, Punsar, Karvonem & Haapakoski, 1985; Peck & Vagero, 1989). Regardless, SES will be adjusted for in the proposed study to avoid potential confounding.

Physical Activity. The association between physical activity (PA) and risk of obesity and CVD is well known. Many studies have concluded that lack of PA in childhood or adulthood can lead to an increased risk of obesity and its associated comorbid disorders (Malina, Bouchard & Bar-Or, 2004). Therefore, it is crucial to control for PA when testing for an association between stature, OwOb and CVD since it is an important modifiable confounder.

Literature Review: Summary

Many adult studies have observed associations between human stature and an individual's OwOb, cardiovascular and other chronic disease risk. In general, both epidemiological and animal studies have shown that greater stature is associated with longevity. Particularly these studies relate cardiovascular mortality and incidence of OwOb and other cardiovascular comorbid disorders with decreased stature even after controlling for significant confounders such as ethnicity, socioeconomic status and physical activity (Hebert et al., 1993; Kannam, Levy, Larson & Wilson, 1994; Parker, Lapane, Lasater & Carleton, 1998; Rich-Edwards, et al., 1995; Yarnell, Limb, Layzell & Baker, 1992). These consistently observed associations have prompted researchers to identify stature as an important marker of OwOb and CVD risk. Researchers explain that although stature may not directly affect disease likelihood, through being a sensitive indicator of growth, nutrition and social environment in early life (which have known effects on disease susceptibility), stature may reflect disease risk. In other words, compared to someone who experiences positive early life growth factors, an individual exposed to negative influences will experience poor development and growth, and an increased risk of disease. The individuals' compromised growth and development is evident in their shorter than normal adult stature. This implies that stature can be used as a marker of childhood influences that directly increase an individual's risk of adiposity, CVD and other related diseases (Asao, Baptiste, Erlinger & Brancati, 2006; Smith et al., 2001). Leg length is consistently shown as the most important stature component, contributing more to overall height than trunk length or any other stature component (Frisancho, 2007). The leg length index is suggested as a more efficient tool then leg length alone since it considers leg length's disease predicting effects but also adjusts for overall height and hence any increase in stature from trunk growth. Unfortunately, studies investigating LLI and OwOb in children are limited.

Study Rationale

OwOb and CVD are very pertinent health concerns for both children and adults. Disease prevention and screening are vital in targeting these problems. This is particularly important among children since their OwOb rates are climbing drastically and they are becoming predisposed very early to future comorbid conditions. The LLI's relation with OwOb may be very helpful in predicting from childhood, future OwOb risk. This will be evaluated through assessing childhood stature components (focusing on the LLI), at the end of the AR period with OwOb development in adolescence, while controlling for genetics, pre and postnatal confounders. It is important to evaluate the association at the end of the critical growth period since that is when postnatal environmental and social influences have most recently affected growth and development. If the LLI is associated with obesity in a clear and specific manner, then it may have potential as an efficient disease risk screening tool.

Study Aim

The primary purpose of this study is therefore to:

Look at the measured LLI at the end of the pre-pubertal growth period (age 9-11 years), and see if it can predict the risk of obesity in adolescence (age 12-14 years) while controlling for important confounders including birth weight, birth order, maternal age at birth, maternal height and BMI, parental smoking, breastfeeding, physical activity and socioeconomic status.

CHAPTER 3: METHODS

Study Data

This study made use of data from both the Physical Health Activity Study Team (PHAST) and the Optimal Growth Study.

Physical Health Activity Study Team. PHAST is a 6 year prospective cohort study of the health and physical fitness of approximately 2,360 students from 75 elementary schools in the District School Board of Niagara. The primary goal of PHAST is to assess the influence of aerobic fitness, motor coordination, body composition and generalized self-efficacy on physical activity, with a focus on children who have Developmental Coordination Disorder (DCD). Study approval was received from both the Human Research Ethics Boards of Brock University and the District School Board of Niagara. The study commenced in September 2004 when the students were in grade 4. Funding for the project was provided by the Canadian Institutes of Health Research (CIHR). Parents were notified via letter/telephone, and informed consent was obtained for all participants. The study protocol is comprised of a parental questionnaire completed in year one by the subject's parents, and annual assessments of the children at their schools. These consist of fitness and body composition assessments, as well as questionnaires about physical activity (Participation Questionnaire), self-efficacy, predilection towards physical activity (CSAPPA scale), and motor coordination appraisals (Bruininks-Oseretsky Test of Motor Proficiency [BOTMP-SF]). Anyone with a physical disability that prevented them from completing any of the assessments properly (i.e. hip replacement surgery, Erb's Palsy, wheelchair) were excluded from the study. On testing day, subjects first completed the questionnaires and then were taken to the school gym for anthropometric measures and the VO2 max shuttle run. Proper attire was required for physical assessments (i.e., shorts, t-shirt, running shoes). For consistency, all anthropometrics were measured twice.

Optimal Growth Study. The Optimal Growth Study (funded by the Social Sciences and Humanities Research Council of Canada [SSHRC]) was implemented in September 2007 on the same cohort of PHAST subjects. This study looks at parental and child early life exposures to various factors that can affect the child's growth and development. Data was collected in the form of Early Life Experience (ELE) and Family Eating and Activity Habits (FEAQ) questionnaires, completed by the child's parent and later returned to home room teachers. The ELE consisted of information regarding the child's birth weight, birth order, prenatal and infancy exposures to cigarette smoke, mother's age, and breastfeeding, whereas the FEAQ focuses on a variety of questions pertaining to the child and parent's eating and physical activity habits.

Study Sample. To answer the research question, this study required baseline stature data (wave 3) and follow-up BMI data (wave 8). Of the 2360 students participating in PHAST, 2229 had completed wave 3 and 1707 completed wave 8. Before merging the two waves by ID number, the data were cleaned for missing ID's. 63 subjects were deleted from wave 3 and 4 subjects from wave 8 for missing ID number. Consequent merging of the two waves resulted in a sample of 1328 subjects who had completed wave 3 and 8 of PHAST. From here, 70 subjects were deleted for incomplete standing height and sitting height (wave 3) and another 91 for incomplete BMI measures (wave 8). This yielded a primary study sample of 1167 subjects with complete PHAST anthropometric data (Figure 3). Early life experience variables were collected from the Optimal Growth Study (OGS). Of the 2303 subjects that the OGS was administered to, 1082 subjects had completed and returned the survey at time of analysis. 36 of those subjects were duplicates and 2 had missing ID numbers and were consequently excluded from analysis. The final early experience subsample consisted of 1044 subjects (Figure 4). To use this early life experience data, we needed to match it with its corresponding PHAST data (Figure 5). ID matching the 1167 PHAST and 1044 OGS subjects yielded a total of 574 subjects with both complete anthropometric and early life data (Figure 5). To evaluate socioeconomic status and parental anthropometrics, data was used from the Parental Questionnaire administered in wave 1 (Figure 6, 7). Of the 1167 children with complete PHAST data, 1161 had complete parental education information. After excluding those with incomplete or extreme parental height, weight and BMI, 719 subjects remained. Following inclusion of only biological mothers, the final parental sample consisted of data from 593 biological mothers (Figure 6).

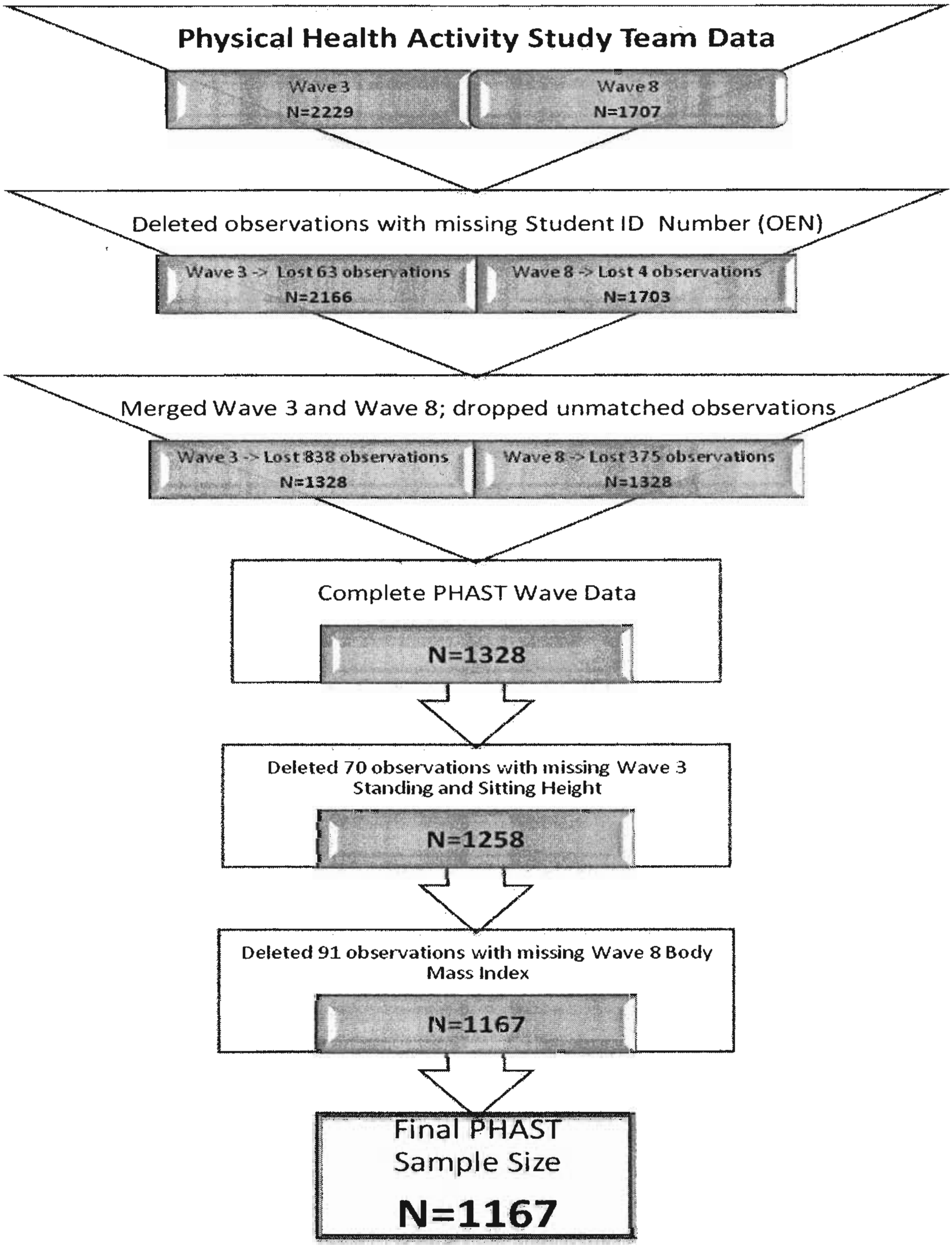


Figure 3: Final Physical Health Activity Study Team Study Sample Size

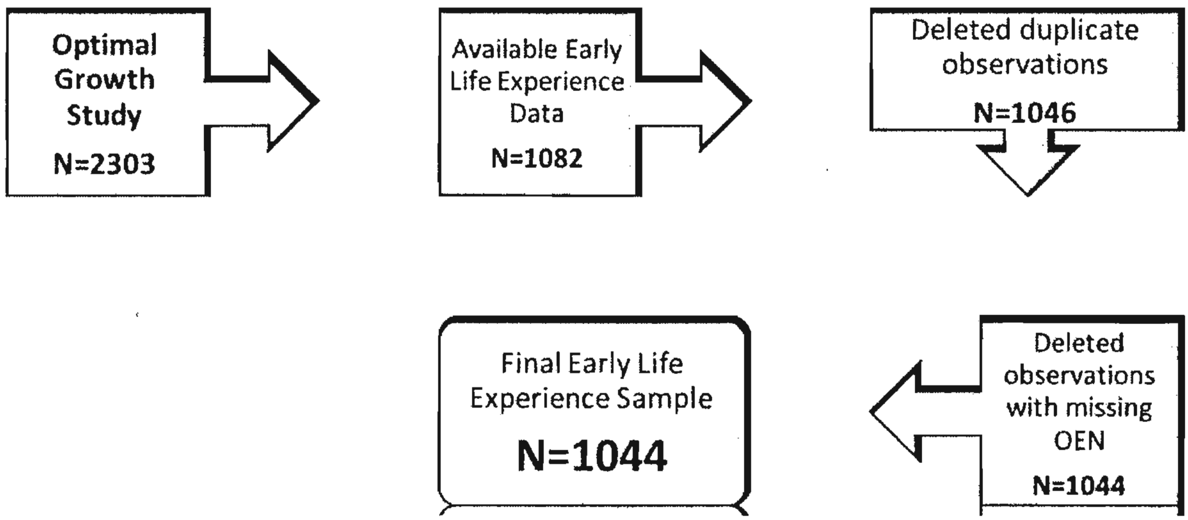


Figure 4: Final Early Life Experience Study Sample Size

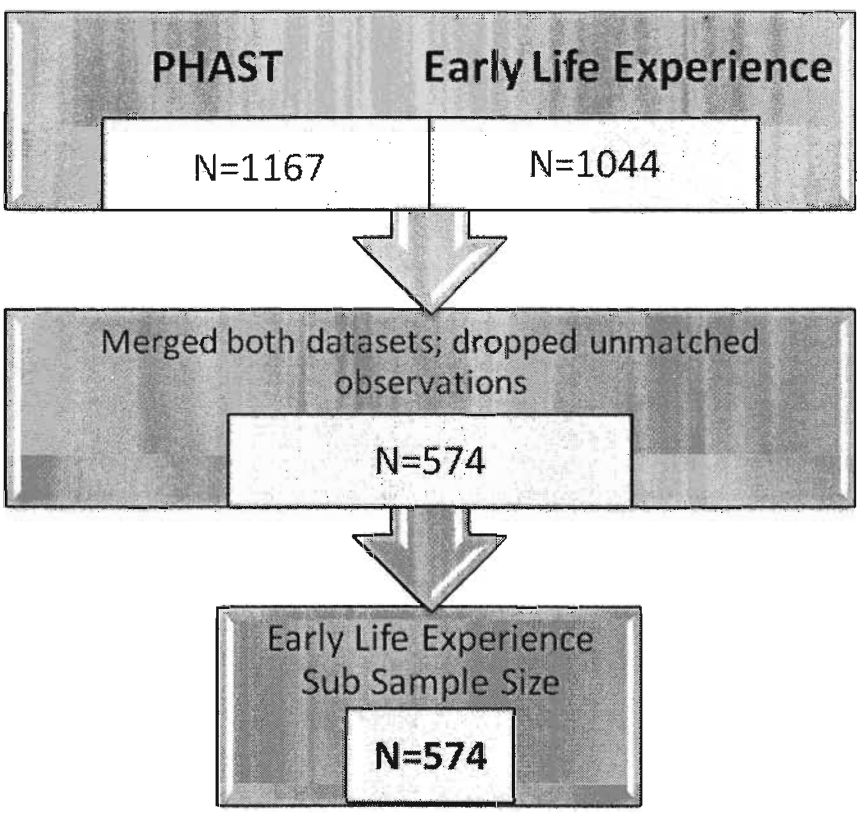


Figure 5: Combined PHAST and Optimal Growth Study Sub Sample Size

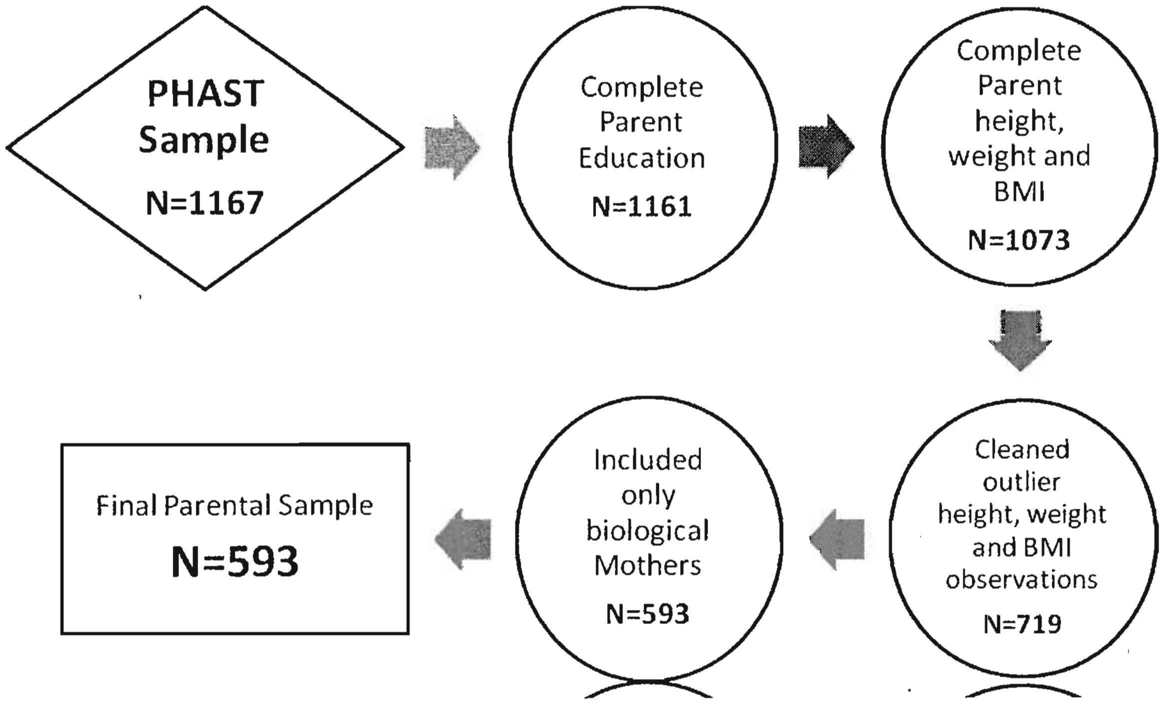


Figure 6: Final Parental Study Sample Size

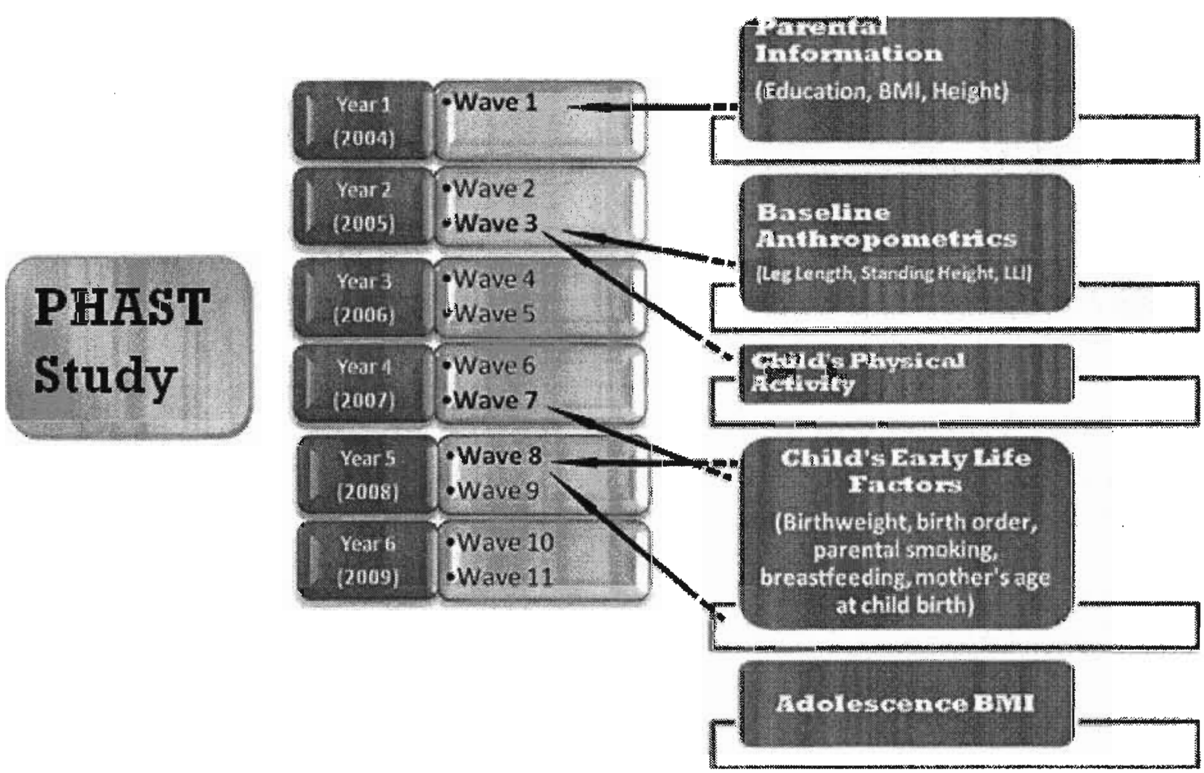


Figure 7: Study Variables by PHAST Year and Wave

Variable Measurement

Anthropometrics. Initially, participants had their height (standing and sitting) and weight measured to the nearest 0.1 cm and 0.1 kg, respectively. Height was measured using a set positioned stadiometer and weight was assessed with an electronic load scale. Standing height was measured without shoes on as the maximum distance from the floor to the highest point on the head, when the subject is facing directly ahead. Sitting height was measured as the maximum distance from the floor to the highest point on the head when the subject is sitting on the floor facing forward. Standing height and weight were used to calculate BMI (kg/m^2). Weight groups were classified according to international cutoffs of overweight and obesity for boys and girls ages 2 to 18 of nationally representative data from Brazil, United Kingdom, Hong Kong, the Netherlands, Singapore, and the United States corresponding to BMI of 25.0 and 30.0 kg/m^2 in adults (Cole, Freeman & Preece, 1998). They were classified as follows: >=95th percentile of all BMIs classified as obese, 85th to 95th percentile as overweight and <85th percentile as normal weight. OwOb was classified as anyone >=85th percentile. Leg length (standing height - sitting height), Leg Length Index (leg length/standing height*100) and Sitting Height Index (sitting height/standing height *100) were also computed. LLI was grouped into tertiles (T) by sex using cutoff values at the 33.3 and 66.7 percentiles: Males: T1 (LLI<49.0), T2 (LLI 49.0-50.3) T3 (LLI>=50.3) Females: T1 (LLI<48.9), T2 (LLI 48.9-50.1) T3 (LLI >=50.1). Waist circumference (WC) was measured to the nearest 0.1cm midway between lowest rib and superior border of iliac crest and hip circumference (HC) was measured at the maximum extension of the buttocks.

Early Life Factors. From the ELE questionnaire (Appendix III), birth weight was recorded in pounds and ounces . The parent's age at child birth was self-reported to the nearest year. The mother's current and pre-pregnancy smoking status was recorded as either 'Yes' or 'No', and her pregnancy and post-pregnancy smoking habits were recorded as 'None, Quit right away, smoked <1 month, <2 months or >3 months. Overall smoking status (SS) was categorized as Never 'none', Sometimes 'smoked either before, during or after pregnancy' and Always 'smoked before, during and after pregnancy'. Pregnancy SS was grouped as Before 'smoked pre-pregnancy', During 'smoked <1 month, <2 months or >3 months' and After 'smoked <1 month, <2months or >3 months'. Breastfeeding recorded as 'Never, 1-6 months, >=6 months' on the questionnaire corresponded to breastfeeding status of 'Never, Briefly and Always'. The child's birth order was recorded as '1^{st}, 2^{nd}, 3^{rd} or more', and the child's age was recorded in years at time of assessment.

Physical Activity. Physical activity was determined using the Participation Questionnaire (PQ) (Appendix I) developed by Hay (1992). The PQ is a 64-item questionnaire that contains multiple choice, Likert-scale type, and free response questions. These questions are used to estimate the amount and type of participation in physical activity under three categories: free time activity, organized activity time, and total time of activities. The number of PQ items is used to measure frequency and nature of physical activity. The PQ has excellent test and re-test correlations: 0.81 for elementary school and 0.89 for high school students (Hay, 1992).

Parental Demographics. A 66-item parental questionnaire was used to collect parental demographic and anthropometric information (Appendix II). The highest level of parental education completed was recorded on the Parental Questionnaire. Parental education levels categorized as <=High School, College and >=University were used to assign 'low, middle and high' SES respectively. The parent's height and weight were self-reported to the nearest inch and lb respectively. They were further converted to meters and kg for calculation of BMI.

Statistical Analysis Methods

All statistical analyses were performed using SAS Version 9.11 (SAS Institute Inc., Cary, NC). Basic descriptive statistics of anthropometric variables (i.e. standing height, sitting height, leg length, LLI, BMI and waist circumference) and age were calculated for the sample. They were stratified by gender and waves to view gender-specific trends at baseline and follow-up. A comparison of anthropometrics was also done for PHAST subjects who were included in overall study sample and those who were not included to visualize differences in study subjects. Similarly between subjects whose parents provided parental education information and those who didn't. The Student's T-test was used to identify significant differences in anthropometric measures between the various stratified groups. Basic descriptive characteristics of early life and parental demographic variables were also tabulated. These included mother's age at child birth, mother's height and BMI, overall and pregnancy smoking status, parental education, child's birth weight, physical activity, birth order and breastfeeding.

Spearman correlations were used to identify the strength of association between wave 8 BMI and wave 3 BMI, standing height, sitting height, leg length, LLI and waist circumference. These were tabulated for the whole sample and further stratified by gender to observe gender-specific trends. Age, sex and waist circumference adjusted partial spearman correlation coefficients were also tabulated. Spearman correlations were created to identify strength between LLI and wave 8 BMI with child's birth weight, mother's age at child birth, mother's height and BMI, and child's physical activity.

General linear models were used to identify means of child's LLI and BMI by parental smoking status, education level, birth order and breastfeeding. They were also used to identify age and waist circumference adjusted mean BMIs by LLI tertile.

The Chi-Square Test of Independence was used to identify if obesity status and LLI tertiles were independent of one another.

Logistic regression models were also created. OwOb was the dependent dichotomous variable and each of the stature components (i.e. LLI, sitting height, standing height, leg length) were in separate models as independent variables. Multivariate logistic regression models were created adjusted for the various confounding variables (i.e. age, sex, waist circumference, birth weight, birth order, breastfeeding, mother's BMI, mother's age at child birth, parent's smoking status, parent's education and child's physical activity). Individual variables were added in a step-wise manner to each subsequent logistic model in order to identify which factor can significantly modify the outcome variable. Odds Ratios from the logistic regression models were used to evaluate the strength of the risk for OwOb. The C-statistic was used to determine accuracy of the various prediction models. Significance level was set to 0.05 for all analyses.

CHAPTER 4: RESULTS

Basic anthropometric characteristics of the study sample stratified by gender are displayed in Tables 1 and 2. At baseline (wave 3), the mean standing height, sitting height, leg length, BMI and waist circumference were similar between boys and girls. However, boys compared to girls were slightly older (10.36 vs. 10.32 yrs respectively, $p=0.0402$) (Table 1). At wave 8, boys were slightly older than girls (13.37 yrs, 13.33 yrs respectively, $p=0.0410$) and also had higher standing height (161.9 cm, 159.5 cm, respectively, $p<0.0001$), longer leg length (82.4 cm, 79.3 cm, respectively, $p<0.0001$) and higher LLI (50.9, 49.7, respectively, $p<0.0001$). Girls had significantly higher sitting height than boys (80.2, 79.5, respectively, $p=0.0091$) (Table 2).

Table 1: Characteristics of Anthropometric Measures at Baseline (Wave 3- 2005)

Variable	Wave 3			
	Males (n=594)		Females (N=573)	
	Mean, SD	**Range**	**Mean, SD**	**Range**
Age (years)	***10.36, 0.34**	**9.67-11.74**	**10.32, 0.31**	**9.55-11.78**
Standing Height (cm)	141.8, 6.58	124.3-163.5	141.6, 6.72	123.3-163.5
Sitting Height (cm)	71.22, 3.43	60.70-85.20	71.43, 3.71	56.00-83.40
Leg Length (cm)	70.53, 4.44	59.50-83.00	70.17, 4.28	59.00-86.50
LLI	49.74, 1.56	44.84-55.75	49.54, 1.54	45.74-56.25
BMI (kg/m^2)	18.74, 3.55	12.96-39.18	18.53, 3.45	12.94-34.47
Waist Circumference (cm)	66.63, 9.64	50.00-112.5	66.21, 9.73	50.00-99.00

Abbreviations: BMI, body mass index, LLI, leg length index
*indicates statistical significance between sexes ($p<0.05$)

Table 2: Characteristics of Anthropometric Measures at Follow-up (Wave 8-2008)

Variable	Wave 8			
	Males (n=594)		Females (N=573)	
	Mean, SD	**Range**	**Mean, SD**	**Range**
Age (years)	***13.37, 0.34**	**12.68-14.75**	**13.33, 0.31**	**12.57-14.80**
Standing Height (cm)	***161.9, 8.69**	**133.6-186.3**	**159.5, 6.47**	**138.0-176.4**
Sitting Height (cm)	***79.51, 4.92**	**64.40-97.30**	**80.20, 3.94**	**68.70-92.90**
Leg Length (cm)	***82.40, 5.33**	**56.40-100.5**	**79.30, 4.35**	**65.40-93.80**
LLI	***50.88, 1.69**	**39.80-60.22**	**49.70, 1.63**	**45.51-55.98**
BMI (kg/m^2)	20.97, 4.06	13.36-40.85	21.30, 4.26	14.45-42.17
Waist Circumference (cm)	74.14, 11.6	50.70-124.5	74.13, 11.2	53.50-122.5

Abbreviations: BMI, body mass index, LLI, leg length index
*indicates statistical significance between sexes ($p<0.05$)

Of the 2330 subjects in the PHAST study, the final study sample consisted of 1167 subjects (594 boys, 573 girls) who had complete anthropometric data for both wave 3 and wave 8. 1163 subjects were excluded from the analyses due incomplete data in either wave 3 (830 subjects [420 boys, 410 girls] or wave 8 (333 subjects [170 boys, 163 girls]. A comparison of anthropometric measures between those who were included and excluded from both waves is displayed in Table 3. At baseline, mean age, standing height, sitting height, leg length and LLI were similar between those included and excluded. However, mean BMI (18.6 vs. 19.5 kg/m2, respectively, $p<0.0001$) and waist circumference (66.4, 68.7cm, respectively, $p<0.0001$) were significantly higher in those excluded from the study. At follow up, all anthropometric measures were similar except waist circumference (74.1, 74.7 cm, respectively, $p<0.0001$) which again was significantly higher in those excluded from the study (Table 3).

Table 3: Comparison of Anthropometric Measures for PHAST subjects excluded and included in study

Variable		Wave 3				Wave 8			
		Included		Excluded		Included		Excluded	
Freq Prop (%)									
Sex:	Male	594	50.90	420	50.60	594	50.90	170	51.05
	Female	573	49.10	410	49.40	573	49.10	163	48.95
Mean, SD									
Age (years)		10.34, 0.32		10.38, 0.39		13.35, 0.32		13.32, 0.33	
Standing Height (cm)		141.7, 6.65		142.4, 6.54		160.7, 7.78		161.1, 7.59	
Sitting Height (cm)		71.32, 3.57		71.86, 3.91		79.85, 4.47		80.00, 4.23	
Leg Length (cm)		70.35, 4.36		70.52, 4.39		80.86, 5.12		81.05, 5.12	
LLI		49.64, 1.55		49.52, 1.81		50.30, 1.76		50.31, 1.72	
BMI (kg/m^2)		***18.64, 3.50**		**19.46, 3.98**		21.13, 4.16		21.21, 4.35	
Waist Circumference (cm)		***66.42, 9.68**		**68.67, 10.9**		***74.14, 11.4**		**74.71, 12.3**	

Abbreviations: BMI, body mass index, LLI, leg length index
*indicates statistical significance between sexes ($p<0.05$)
Note: Refer to Figure 3 for study sample

Characteristics of the Early Life Experience sub-sample including physical activity information are displayed in Table 4. Approximately 281 boys and 293 girls provided early life data. The mean child birth weight was 7.5 lb with a range of 2.4-13.3 lb and mean mother's age at child birth was 28.9 years with range 16.0-40.0 years. The mean mother's height was 168.2 cm and mean BMI was 24.0 kg/m^2 with range 14.0-54.3. The child's current physical activity level ranged from 1.0-36.0 with a mean of 14.0. 46.6% of the sub-sample were 1st born children, 36.9% were 2nd born and 16.4% were 3rd born or higher. 25.3% mother's smoked before pregnancy, 19.7% continued during pregnancy and 18.3% continued until after pregnancy. Overall, 72.95% of the mother's never smoked, 14.6% sometimes smoked and 12.5% always smoked. 19.8% of the sub-sample were never breastfed, 42.7% were breastfed at some point and 37.5% were always breastfed. 24.3% of the children's parents had less than high school education, 53.1% had college and 22.6% had university or higher education (Table 4).

Table 4: Characteristics of Early Life Experience factors and other childhood confounders

Variable		N	Mean, SD	Range
Child's Birth weight (lb)		543	7.53, 1.29	2.44 - 13.30
Mother's Age at Birth (years)		352	28.87, 4.47	16.00 - 40.00
Mother's Height (cm)		358	168.2, 17.8	133.4 - 251.5
Mother's BMI (kg/m^2)		313	24.03, 4.96	14.00 - 54.30
Physical Activity		492	14.03, 5.86	1.00 – 36.00
			Freq	**Prop (%)**
Sex:	Male		281	48.95
	Female		293	51.05
Birth Order:	1		264	46.64
	2		209	36.93
	>=3		93	16.43
Overall SS:	Never		391	72.95
	Sometimes		78	14.55
	Always		67	12.50
Pregnancy SS:	Before		142	25.31
	During		110	19.71
	After		99	18.27
Breastfeeding	Never		111	19.82
	Briefly		239	42.68
	Always		210	37.50
Education	<=High School		104	24.36
	College		239	55.97
	>=University		84	19.67

Abbreviation: SS, smoking status
Variables described: Overall SS: Never 'none', Sometimes 'smoked either before, during or after pregnancy', Always 'smoked before, during and after pregnancy'; Breastfeeding: Never 'none', Briefly '1-6 months', Always '>=6 months'.
Note: Pregnancy SS shows the changes in frequency of smokers from before to after pregnancy.

A comparison of anthropometric measures between Early Life Experience sub sample subjects who provided parental education information and those who didn't are displayed in Table 5. Parental education information was available for 427 subjects (208 boys, 219 girls) while 147 subjects (73 boys, 74 girls) did not have the data. At baseline, there was no significant difference in age, standing height, sitting height, leg length, LLI, BMI or waist circumference between subjects who provided parental education information and those who did not. At wave 8 however, children whose parental education information was not available had higher waist circumference than those whose parental education information was available (74.8 vs. 72.7 cm, $p<0.0001$); while all other variables were similar (Table 5).

Mean BMI by baseline LLI tertile stratified by gender are displayed in Figure 8. Both males and females followed a similar trend of significant decrease in BMI with LLI tertile increase (Males: 21.5, 20.9, 20.5; Females: 21.8, 21.3, 20.7; for T1, T2, T3, respectively, p for trend <0.0001) (Figure 8).

Table 5: Comparison of Anthropometric Measures for sub-sample study subjects who did and did not provide Parental Education information

Variable		Wave 3				Wave 8			
		Edu Info		No Edu Info		Edu Info		No Edu Info	
Freq	**Prop (%)**								
Sex:	Male	208	48.71	73	49.66	208	48.71	73	49.66
	Female	219	51.29	74	50.34	219	51.29	74	50.34
Mean, SD									
Age (years)		10.31, 0.31		10.28, 0.29		13.32, 0.31		13.30, 0.29	
Standing Height (cm)		141.7, 6.65		141.2, 6.71		160.7, 7.49		160.6, 7.74	
Sitting Height (cm)		71.31, 3.51		71.20, 3.38		79.93, 4.39		79.96, 4.32	
Leg Length (cm)		70.36, 4.52		70.05, 4.32		80.82, 5.01		80.69, 5.05	
LLI		49.65, 1.62		49.57, 1.37		50.27, 1.78		50.21, 1.70	
BMI (kg/m^2)		18.39, 3.44		18.75, 3.39		20.76, 4.14		21.35, 4.15	
Waist Circumference (cm)		65.77, 9.49		66.25, 9.59		***72.74, 11.2**		**74.77, 12.2**	

Abbreviations: BMI, body mass index, LLI, leg length index
*indicates statistical significance between education information provided and not provided ($p<0.05$)

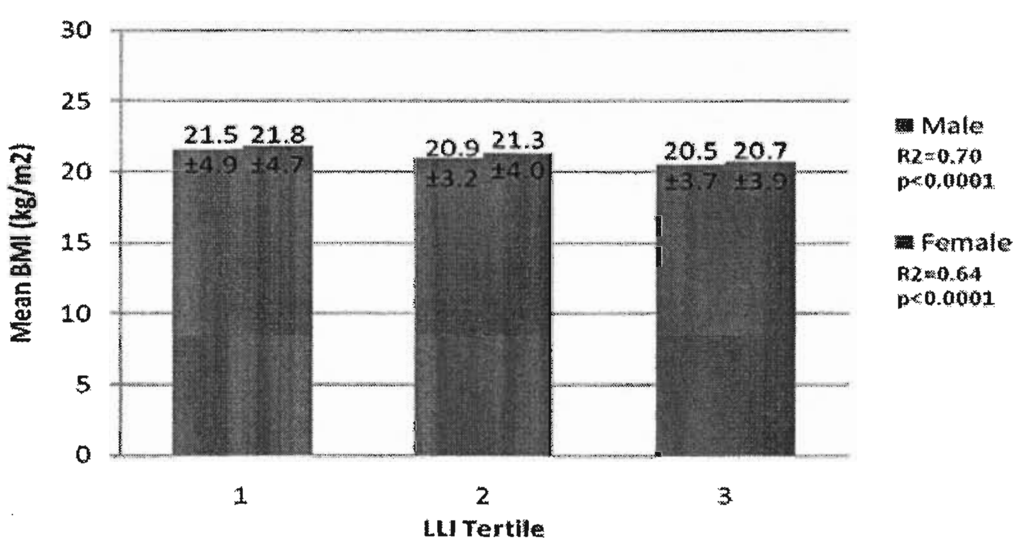
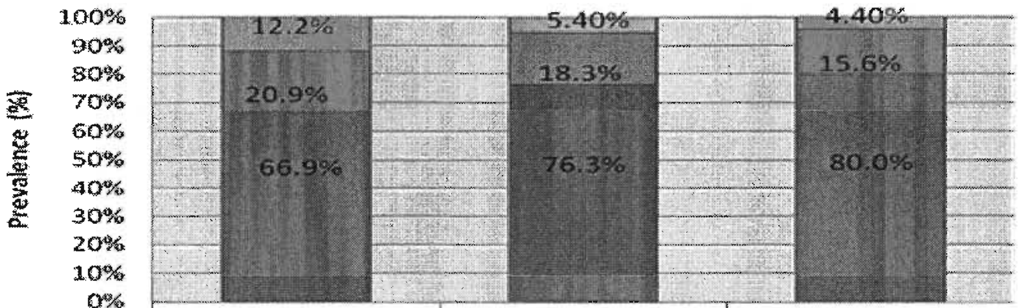


Figure 8: Mean (±SD) of Body Mass Index by Leg Length Index Tertile adjusted for baseline age and waist circumference.
Notes: p is for observed trend
LLI tertile cutoffs: Males: T1 (LLI<49.0), T2 (LLI 49.0-50.3) T3 (LLI>=50.3)
Females: T1 (LLI<48.9), T2 (LLI 48.9-50.1) T3 (LLI >=50.1).

Figure 9 shows the prevalence of overweight and obesity in each LLI tertile. Prevalence of both overweight and obesity significantly decrease with every increase in LLI tertile (Ow: 20.9%, 18.3%, 15.6%; Ob: 12.2%, 5.40%, 4.40%; for T1, T2, T3, respectively, p for trend <0.0001) (Figure 9).



	1	2	3
Ob	47	21	17
Owt	81	71	61
Normal	259	297	312 *p<0.0001

Figure 9: Prevalence of OwOb by Leg Length Index Tertile.
Notes: p is for observed trend
LLI tertile cutoffs: Males: T1 (LLI<49.0), T2 (LLI 49.0-50.3) T3 (LLI>=50.3)
Females: T1 (LLI<48.9), T2 (LLI 48.9-50.1) T3 (LLI >=50.1).

Table 6 displays spearman correlation coefficients between wave 3 BMI, wave 3 waist circumference and wave 8 BMI. Wave 3 BMI has strong correlations with both wave 8 BMI (r=0.8616, p<0.0001) and wave 3 waist circumference (r=0.8583, p<0.0001). The strength and direction of the correlations are very similar for both genders (Table 6).

Table 6: Spearman Correlation Coefficients between baseline waist circumference, BMI and Wave 8 BMI

	Wave 3 BMI					
	Males		*Females*		*Combined*	
Variable	**r**	**p-value**	**r**	**p-value**	**r**	**p-value**
Waist circumference	**0.8530**	**<0.0001**	**0.8598**	**<0.0001**	**0.8583**	**<0.0001**
Wave 8 BMI	**0.8748**	**<0.0001**	**0.8576**	**<0.0001**	**0.8616**	**<0.0001**

Abbreviation: BMI, body mass index

The spearman correlation coefficients between baseline standing height, sitting height, leg length, LLI and wave 8 BMI are shown in Table 7. Standing height, sitting height and leg length had a significant positive correlation with BMI (r= 0.265, 0.353, 0.129, respectively, p<0.0001) while LLI had a significant negative correlation (r=-0.165, p<0.0001). After adjusting for baseline age and sex, the correlation coefficients between BMI and the various stature components stayed similar. Further adjusting for waist circumference produced negative correlations between standing height, leg length and LLI with BMI (r=-0.160, -0.217, -0.219, respectively, p<0.0001). The correlation between BMI and sitting height became insignificant (r=0.011, p=0.7188) (Table 7).

Table 7: Spearman Correlation Coefficients between various Stature variables and Wave 8 BMI

	Wave 8 BMI		Wave 8 BMI[a]		Wave 8 BMI[b]	
Variable	**r**	**p-value**	**r**	**p-value**	**r**	**p-value**
Standing Height	**0.2650**	**<0.0001**	**0.2574**	**<0.0001**	**-0.1598**	**<0.0001**
Sitting Height	**0.3529**	**<0.0001**	**0.3454**	**<0.0001**	0.0106	0.7188
Leg Length	**0.1290**	**<0.0001**	**0.1192**	**<0.0001**	**-0.2169**	**<0.0001**
LLI	**-0.1645**	**<0.0001**	**-0.1685**	**<0.0001**	**-0.2189**	**<0.0001**

Abbreviations: LLI, Leg Length Index; BMI, body mass index
[a]adjusted for baseline age and sex
[b]adjusted for baseline age, waist circumference and sex

Stratifying by gender provided similar trends in strength and direction of the correlations for males. Among females however, the correlation coefficient between standing height and wave 8 BMI was negative (r=-0.068), but not significant after adjusting for age and waist circumference; while all other variables stayed the same (Table 8).

Table 8: Spearman Correlation Coefficients between various Stature variables and Wave 8 BMI stratified by sex

Variable	Wave 8 BMI r	Wave 8 BMI p-value	Wave 8 BMI[c] r	Wave 8 BMI[c] p-value	Wave 8 BMI[d] r	Wave 8 BMI[d] p-value
Males						
Standing Height	0.2394	<0.0001	0.2236	<0.0001	-0.2662	<0.0001
Sitting Height	0.3363	<0.0001	0.3263	<0.0001	-0.0751	0.0679
Leg Length	0.1090	0.0078	0.0884	0.0314	-0.2850	<0.0001
LLI	-0.1656	<0.0001	-0.1798	<0.0001	-0.2168	<0.0001
Females						
Standing Height	0.2922	<0.0001	0.2913	<0.0001	-0.0680	0.1048
Sitting Height	0.3671	<0.0001	0.3644	<0.0001	0.0792	0.0589
Leg Length	0.1556	0.0002	0.1530	0.0002	-0.1496	0.0003
LLI	-0.1535	0.0002	-0.1538	0.0002	-0.2128	<0.0001

Abbreviations: LLI, Leg Length Index; BMI, body mass index
[c]adjusted for baseline age
[d]adjusted for baseline age and waist circumference

The odds ratios of OwOb for standing height, sitting height, leg length and LLI are displayed in Table 9. The unadjusted odds ratios are shown in model 1. Confounder adjusted odds ratios are displayed in model 2 (adjusted for baseline age and sex) and model 3 (adjusted for baseline age, waist circumference and sex). Model 1 odds of OwOb [OR (95% CI)] for every one centimeter (cm) increase in standing height, sitting height and leg length were 1.10 (1.08-1.13), 1.29 (1.23-1.35) and 1.07 (1.04-1.10), respectively. Every one unit increase in LLI, on the other hand, decreased odds of OwOb by 21.5% [0.79 (0.71-0.86)]. Model 2 followed similar trends in odds ratios for all variables. Further adjusting for waist circumference however (model 3), changed the direction of the odds ratios for standing height [0.93 (0.90-0.96)], sitting height [0.97 (0.91-1.03)] and leg length [0.88 (0.84-0.92)]. The direction of LLI remained consistent [0.76 (0.66-0.87)] (Table 9).

Table 9: Odds Ratios of OwOb for various Stature Components

	Model 1		Model 2[a]		Model 3[b]	
Variable	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Standing Height	***1.104**	**1.080- 1.129**	***1.080**	**1.057- 1.104**	***0.930**	**0.898- 0.962**
Sitting Height	***1.287**	**1.230- 1.347**	***1.217**	**1.166- 1.269**	0.968	0.909- 1.030
Leg Length	***1.070**	**1.036- 1.104**	***1.048**	**1.016- 1.081**	***0.878**	**0.835- 0.923**
LLI	***0.785**	**0.714- 0.863**	***0.810**	**0.739- 0.886**	***0.758**	**0.664- 0.865**

Abbreviations: LLI, Leg Length Index; OR, Odds Ratio; CI, Confidence Interval
[a]adjusted for baseline age and sex
[b]adjusted for baseline age, waist circumference and sex
*Indicates statistical significance ($p<0.0001$)

Table 10 displays the spearman correlation coefficients between early life factors (birth weight, mother's age at birth, mother's height, mother's BMI) and physical activity with the child's baseline LLI and wave 8 BMI. LLI had a negative borderline significant correlation with mother's BMI (r= -0.0932, p=0.0701) while correlations for birth weight, physical activity, mother's age at birth and mother's height were all insignificant (Table 10). Similarly, the child's BMI had a positivecorrelation with mother's BMI (r=0.2580, p<0.0001) however insignificant correlations with other early life factors and physical activity (Table 10).

Table 10: Spearman Correlation Coefficients between LLI, Wave 8 BMI and Early Life Factors including child's Physical Activity

	Baseline LLI		Wave 8 BMI	
Variable	**r**	**p-value**	**r**	**p-value**
Birth weight	0.0560	0.1925	0.0613	0.1508
Mother's Age at Birth	0.0142	0.7374	-0.0515	0.2242
Mother's Height	0.0718	0.1374	-0.0677	0.1613
Mother's BMI	-0.0932	0.0701	***0.2757**	**<0.0001**
Physical Activity	0.0217	0.6307	-0.0501	0.2673

Abbreviations: LLI, Leg Length Index; BMI, body mass index;

The mean levels of LLI and BMI by parental smoking status, child's birth order, child's breastfeeding status and parental education are displayed in figures 10, 11, 12 and 13 respectively. For the parental smoking status - Never, Sometimes, Always Smoking, the mean LLI were 49.7, 49.5, 49.2, respectively (p for trend <0.0001) and mean BMI were 20.7, 20.9, 21.8 kg/m^2 respectively (p for trend= 0.072) (Figure 10). The child's birth order- 1, 2, >=3, showed a borderline significant trend in mean LLI levels (49.8, 49. 4, 49.6 respectively, p for trend= 0.077) while the increasing trend observed for BMI was insignificant (20.8, 21.0, 21.1 kg/m^2 respectively, p for trend= 0.461) (Figure 11). Breastfeeding status- Never, Sometimes, Always, showed an increasing trend in LLI (49.5, 49.6, 49.8 respectively) and decreasing trend in BMI (21.2, 20.9, 20.7 kg/m^2 respectively), however neither of the trends were significant (Figure 12). The trends observed for parental education level- <=High School, College, >=University, were 49.7, 49.6, 49.8 respectively for LLI and 20.6, 21.0, 20.2 kg/m^2 respectively for BMI; however neither of these trends were significant (Figure 13).

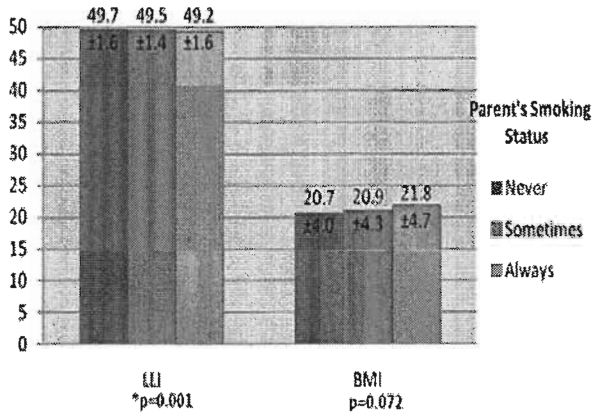


Figure 10: Mean (±SD) LLI and BMI by Parental Smoking Status
Note: p is for observed trend

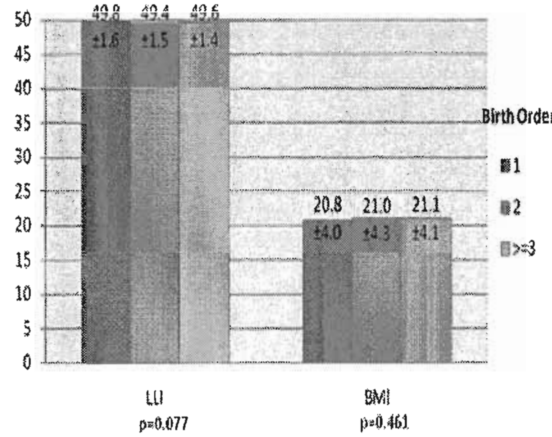


Figure 11: Mean (±SD) LLI and BMI by Child's Birth Order
Note: p is for observed trend

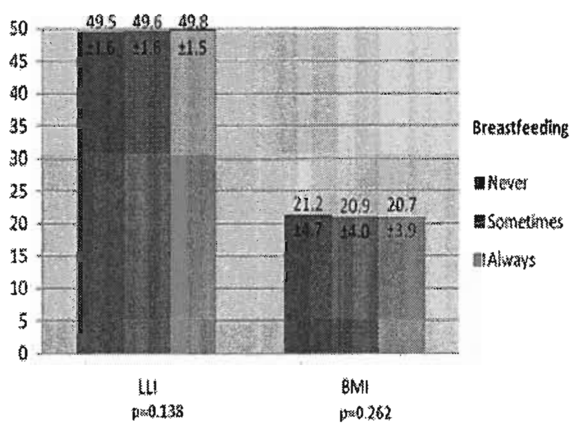


Figure 12: Mean (±SD) LLI and BMI by Child's Breastfeeding Status
Note: p is for observed trend

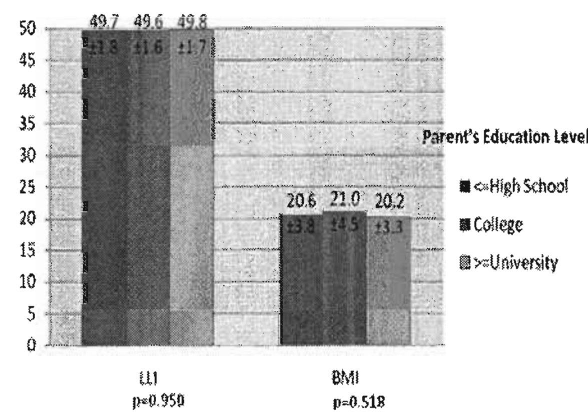


Figure 13: Mean (±SD) LLI and BMI by Parental Education Level
Note: p is for observed trend

Odds Ratios of OwOb in wave 8 predicted by LLI, standing height, sitting height and leg length in wave 3 are shown in tables 11-14. The tables refer to five models: Model 1 (adjusted for baseline age, sex and waist circumference), Model 2 (adjusted same as model 1, further including birth weight, birth order and breastfeeding), Model 3 (adjusted same as model 2, further including mother's BMI and mother's age at child birth), Model 4 (adjusted same as model 3, further including parental smoking and education level) and Model 5 (adjusted same as model 4, further including physical activity).

Table 11 displays OwOb odds ratios for standing height. Model 1 indicates that a 1 cm increase in standing height significantly decreases odds of OwOb by 7% [OR (95% CI]: [0.930 (0.898-0.962)]. After adjusting for confounders in models 2, 3, 4 and 5, the odds ratios become insignificant [0.968 (0.919-1.021)], [0.969 (0.904-1.038)], [0.976 (0.909-1.048)], [0.969 (0.897-1.047)] respectively. An increase in mother's BMI, increased odds of OwOb in both models 3 [1.092 (1.004-1.187)] and 4 [1.109 (1.015-1.212)]. Higher birth order increased OwOb odds by 95.9% [1.959 (1.011-3.794)]. All other confounders did not significantly affect odds of OwOb (Table 11).

Table 12 displays the OwOb odds ratios for sitting height. The odds ratios were insignificant in models 1, 2 and 3 ([0.968 (0.91-1.03)], [1.054 (0.96-1.16)], [1.118 (0.98-1.27)] respectively). After adjusting for parent's smoking and education level in model 4 however, every 1 cm increase in sitting height increased odds of OwOb by 16.2% [1.162 (1.007-1.341)]. Further adjusting for physical activity in model 5 made the odds ratio insignificant [1.141 (0.975-1.335)]. Higher mother's BMI increased odds of OwOb in both models 3 [1.093 (1.004-1.190)] and 4 [1.113 (1.016-1.220)]. Higher birth order increased the odds of OwOb by 1.94 times in model 4 [1.938 (1.029-3.650)] and 2.13 times in model 5 [2.129 (1.089-4.162)]. Higher mother's age at child birth decreased OwOb odds in model 5 [0.884 (0.791-0.987)]. All other early life confounders and physical activity did not significantly affect OwOb in other models (Table 12).

Table 13 shows the OwOb odds ratios for the leg length component. A 1 cm increase in leg length caused a significant decrease in odds of OwOb in all models: 12.2 % [0.878 (0.835-0.923)], 9.0% [0.910 (0.843-0.982)], 12.0% [0.88 (0.801-0.976), 11.4% [0.886 (0.801-0.981), 11.9% [0.881 (0.788-0.984)] for model 1, 2, 3, 4, 5 respectively. Higher mother's BMI in model 4 increased odds of OwOb [1.098 (1.002-1.204)]. All other early life confounders were insignificant (Table 13).

Table 14 displays the OwOb odds ratios for LLI. In all models, every one unit increase in LLI decreased odds of OwOb. The odds significantly decreased in every subsequent adjusted model by; 24.2% [0.758 (0.664-0.865)], 27.5% [0.725 (0.589-0.892)], 37.8% [0.622 (0.472-0.820)], 42.5% [0.575 (0.424-0.779)], 43.6% [0.564 (0.400-0.796)] for models 1, 2, 3, 4, 5 respectively. Higher mother's age at child birth decreased OwOb odds in both model 4 [0.899 (0.809-0.999)] and model 5 [0.880 (0.787-0.985)]. All other confounders did not show significant odds for OwOb (Table 14).

The LLI prediction models had consistently higher c-statistic values then other stature prediction models (c-stat: 0.925, 0.929, 0.937, 0.944 and 0.945 for models 1, 2, 3, 4 and 5 respectively). C-statistics for model 5 were highest for all stature components (standing height, sitting height, leg length and LLI, c-stat: 0.928, 0.932, 0.934, 0.945 respectively) (Tables 11-14).

Table 11: Odds Ratios of OwOb predicted by Standing Height, Early Life Experience Factors and other childhood confounders.

	OwOb Prediction Models									
	OR 95% CI									
Variable	Model 1[a]		Model 2[a]		Model 3[a]		Model 4[a]		Model 5[a]	
Standing Height	***0.930**	**0.898- 0.962**	0.968	0.919- 1.021	0.969	0.904- 1.038	0.976	0.909- 1.048	0.969	0.897- 1.047
Birth Weight			1.027	0.807- 1.307	0.999	0.711- 1.404	0.994	0.694- 1.422	1.082	0.727- 1.612
Birth Order			1.147	0.772- 1.704	1.375	0.775- 2.439	1.730	0.933- 3.209	***1.959**	**1.012- 3.794**
Breastfeeding			0.919	0.614- 1.374	0.796	0.473- 1.338	0.722	0.406- 1.283	0.770	0.411- 1.443
Mother's BMI					***1.092**	**1.004- 1.187**	***1.109**	**1.015- 1.212**	1.080	0.984- 1.185
Mother's Age at Birth					0.974	0.890- 1.065	0.931	0.844- 1.027	0.905	0.814- 1.007
Parent's SS							1.088	0.629- 1.882	1.240	0.690- 2.231
Parent's Education							1.354	0.725- 2.531	1.495	0.746- 2.993
Physical Activity									0.963	0.895- 1.037
C-stat	**0.921**		**0.924**		**0.924**		**0.927**		**0.928**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a] Models also adjusted for baseline age, waist circumference and sex
Note: Parent's SS refers to the overall smoking status

Table 12: Odds Ratios of OwOb predicted by Sitting Height, Early Life Experience Factors and other childhood confounders.

OwOb Prediction Models

Variable	Model 1[a] OR	Model 1[a] 95% CI	Model 2[a] OR	Model 2[a] 95% CI	Model 3[a] OR	Model 3[a] 95% CI	Model 4[a] OR	Model 4[a] 95% CI	Model 5[a] OR	Model 5[a] 95% CI
Sitting Height	0.968	0.909- 1.030	1.054	0.955- 1.163	1.118	0.983- 1.271	***1.162**	**1.007- 1.341**	1.141	0.975- 1.335
Birth Weight			0.984	0.775- 1.250	0.932	0.666- 1.306	0.918	0.641- 1.315	0.986	0.662- 1.467
Birth Order			1.180	0.797- 1.749	1.440	0.809- 2.561	***1.938**	**1.029- 3.650**	***2.129**	**1.089- 4.162**
Breastfeeding			0.895	0.599- 1.336	0.774	0.460- 1.303	0.682	0.383- 1.214	0.723	0.387- 1.351
Mother's BMI					***1.093**	**1.004- 1.190**	***1.113**	**1.016- 1.220**	1.082	0.984- 1.190
Mother's Age at Birth					0.957	0.874- 1.047	0.904	0.816- 1.001	***0.884**	**0.791- 0.987**
Parent's SS							1.048	0.600- 1.830	1.184	0.650- 2.156
Parent's Education							1.232	0.658- 2.306	1.394	0.689- 2.821
Physical Activity									0.959	0.890- 1.034
C-stat	**0.918**		**0.922**		**0.927**		**0.932**		**0.932**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a]Models also adjusted for baseline age, waist circumference and sex
Note: Parent's SS refers to the overall smoking status

Table 13: Odds Ratios of OwOb predicted by Leg Length, Early Life Experience Factors and other childhood confounders.

	OwOb Prediction Models									
	OR 95% CI									
Variable	Model 1[a]		Model 2[a]		Model 3[a]		Model 4[a]		Model 5[a]	
Leg Length	***0.878**	**0.835- 0.923**	***0.910**	**0.843- 0.982**	***0.884**	**0.801- 0.976**	***0.886**	**0.801- 0.981**	***0.881**	**0.788- 0.984**
Birth Weight			1.051	0.826- 1.339	1.076	0.759- 1.542	1.066	0.741- 1.533	1.146	0.765- 1.717
Birth Order			1.099	0.735- 1.643	1.298	0.722- 2.334	1.664	0.883- 3.136	1.896	0.961- 3.744
Breastfeeding			0.944	0.631- 1.412	0.824	0.489- 1.388	0.733	0.411- 1.310	0.769	0.407- 1.450
Mother's BMI					1.079	0.990- 1.177	***1.098**	**1.002- 1.204**	1.073	0.975- 1.180
Mother's Age at Birth					0.974	0.891- 1.066	0.928	0.840- 1.025	0.903	0.811- 1.006
Parent's SS							0.970	0.549- 1.713	1.101	0.602- 2.014
Parent's Education							1.414	0.751- 2.660	1.495	0.739- 3.023
Physical Activity									0.963	0.893- 1.037
C-stat	**0.924**		**0.926**		**0.930**		**0.934**		**0.934**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a]Models also adjusted for baseline age, waist circumference and sex
Note: Parent's SS refers to the overall smoking status

Table 14: Odds Ratios of OwOb predicted by LLI, Early Life Experience Factors and other childhood confounders.

	OwOb Prediction Models									
	OR	95% CI								
Variable	Model 1[a]		Model 2[a]		Model 3[a]		Model 4[a]		Model 5[a]	
LLI	***0.758**	**0.664- 0.865**	***0.725**	**0.589- 0.892**	***0.622**	**0.472- 0.820**	***0.575**	**0.424- 0.779**	***0.564**	**0.400- 0.796**
Birth Weight			1.026	0.807- 1.303	1.068	0.753- 1.514	1.061	0.734- 1.532	1.114	0.741- 1.675
Birth Order			1.091	0.728- 1.635	1.269	0.697- 2.309	1.753	0.908- 3.385	1.943	0.956- 3.945
Breastfeeding			0.937	0.627- 1.400	0.829	0.490- 1.403	0.699	0.388- 1.262	0.710	0.373- 1.349
Mother's BMI					1.070	0.978- 1.171	1.096	0.995- 1.208	1.070	0.968- 1.184
Mother's Age at Birth					0.961	0.878- 1.053	***0.899**	**0.809- 0.999**	***0.880**	**0.787- 0.985**
Parent's SS							0.832	0.449- 1.507	0.916	0.483- 1.737
Parent's Education							1.379	0.726- 2.619	1.415	0.690- 2.901
Physical Activity									0.953	0.882- 1.030
C-stat	**0.925**		**0.929**		**0.937**		**0.944**		**0.945**	

Abbreviation: LLI, Leg Length Index; SS, smoking status; c-stat, c-statistic
[a] Models also adjusted for baseline age, waist circumference and sex
Note: Parent's SS refers to the overall smoking status

CHAPTER 5: DISCUSSION

This analysis of longitudinal pediatric physical health data demonstrated that both childhood leg length and leg length index had predictive abilities for overweight and obesity risk in adolescence. The leg length index prediction models had the highest accuracy and showed consistent relationships after adjusting for all demographic and early life confounders. Thus this study suggested that of the four stature components under study, the leg length index may provide best prediction of OwOb from mid-childhood. To confirm this finding, further analyses were also conducted. After excluding all subjects who were OwOb at baseline, it was found that those with lower LLI at baseline had higher odds of becoming OwOb at wave 8 (adjusted for hip circumference, age and sex). It was very similar for other stature components (Appendix IV).

This research found that higher childhood leg length index associated with decreased likelihood of adolescence OwOb. Specifically OwOb prevalence was highest among subjects who were in the first leg length index tertile (33.1%), lower for second tertile (23.7%) and lowest for third tertile subjects (20.0%) (p for trend <0.0001). It is evident that higher relative leg growth in childhood is associated with a lower risk of adolescence OwOb development. The results from this study further revealed that the relationship between relative leg growth and adiposity was modified only by the child's parental smoking status; children from parents who smoked had lower LLI and an increased risk of adolescence OwOb.

Relation to Previous Research

Findings from this study are consistent with results from other field-based adult and child studies which assessed relationships between stature and adiposity (Asao et al., 2006; Davey Smith et al., 2001; Gunnell et al., 2003; Pliakas & McCarthy, 2009). A major limitation to these studies, however, was their cross-sectional nature which did not allow for OwOb prediction modeling. The use of longitudinal data in this study overcame this limitation to a degree where we could accurately assess and comment on leg length index's potential as an OwOb prediction tool. After controlling for potential confounders, we found that parental smoking status could significantly lower the LLI. This was consistent with studies done on adults which had reported smoking's adverse effects on childhood stature. However, adult studies have also identified other early life factors such as the biological mother's age at birth, socioeconomic status, breastfeeding and birth weight as having profound effects on stature related components (Karaolis-Danckert et al., 2008; Sharma et al., 2008; Oken et al., 2008). The current study did not find significant associations between LLI and other early life factors or child's physical activity. The discrepancy merits for further investigation on important LLI modifying factors that can contribute to childhood and adolescence OwOb.

The current study observed consistent relationships between LLI and OwOb even after adjusting for most prenatal, postnatal, and genetic confounders. This implies an underlying mechanism of association between LLI and adiposity. Thus this study provides supportive evidence for Karsenty's research (2006).

Karsenty suggested of bones metabolic potential in the body through a hormonal feedback regulation of blood sugar and fat deposits. It was implied that longer bones had more osteoblast activity which produced more osteocalcin and increased its hormonal activity (Karsenty, 2006). This led to many metabolically desirable effects including; increased proliferation of pancreatic beta cells, increased insulin secretion, lower blood sugar, increased insulin sensitivity, decreased visceral fat and increased energy expenditure. In other words, individuals with increased leg length (i.e. longer bones) might have more osteocalcin activity and were thus metabolically protected from an increased risk of overweight and obesity. This explanation further sheds light on the positive relationship between maternal smoking and risk of childhood obesity which although has been well documented in the literature, however has not plausibly been explained. Since children of mothers who smoke experience decreased growth and development, they would have relatively short legs (lower bone mass) and lower osteocalcin activity; thus contributing to a higher risk of OwOb due to the metabolic effects of lower osteocalcin levels. Although this is a plausible explanation, future research is needed to identify the actual metabolic mechanism through which osteocalcin works to lower risk of adiposity.

Implications of Findings

Findings from this study suggest a different perspective in fighting the OwOb epidemic. Children who have shorter relative leg growth should be given particular attention in terms of OwOb prevention as they seem to acquire OwOb much easier. Therefore in conjunction with assessing known OwOb risk factors in childhood, a child's LLI should be evaluated equivalently. One way of accomplishing this could be through monitoring the child's stature at the end of the childhood critical growth period. For example, through identifying and grouping measured LLI into low, medium and high groups, the child's relative risk of OwOb could be estimated, where those in the lower group would have the highest risk. A similar strategy was employed in this study where the gender-specific LLI tertile cutoffs were used to create these groups and to visualize the prevalence of OwOb by the different levels of relative leg growth. The high, mid and low risk OwOb groups corresponded to the <33.3%, 33.3% ~ 66.7% and >=66.7% tertiles respectively. It was found that the prevalence of overweight and obesity was significantly different between the leg length index groups; those in the lower LLI tertile having highest OwOb prevalence. An OwOb identification tool can be developed through conducting a similar analysis with more universal and confounder-adjusted cutoffs for low, mid and high risk LLI. This tool may contribute significantly to public health OwOb prevention initiatives where high risk children could be identified early and subsequent prevention efforts could be implemented to lower their risk of future adiposity.

Future Research Direction

Future research should investigate utilization of LLI in predicting OwOb for children younger than 8 years. Analysis of longitudinal health data of children 0-8 years would be ideal. Creating LLI risk groups for these children may provide important adiposity risk insight. The LLI of children younger than 4 years is primarily reflective of influences that affected growth and development in the prenatal critical growth period. Since the majority of leg growth occurs in the childhood AR period, it is suspected that LLI measured prior to the AR would not have as profound OwOb risk predictive abilities as that measured after AR. Nevertheless, because the prenatal critical growth period has significant impacts on the child's stature, LLI measured between 0-4 years may have some potential in assessing OwOb risk far before it has become phenotypically evident. Accordingly, LLI cutoffs can be created for a wide age range of children and consequent OwOb prevention strategies can be implemented for a high risk child at any age.

Future research should also focus on identifying other potential demographic, prenatal or postnatal confounders that may modify the association between LLI and OwOb. One way to achieve this may be through a comparative analysis of OwOb and normal weight children in the lower LLI tertile. Identifying factors that are similar and dissimilar between the two weight groups may provide interesting insight into factors that can contribute to OwOb.

Another valuable avenue for future research might be to try to identify efficient ways to prevent OwOb among those who have shorter LLI or leg length. For instance, investigating whether increased physical activity in childhood can reduce the risk of future OwOb among those with lower LLI, or perhaps even investigating the different nutrients or caloric intakes that can be used to lower the risk of OwOb among those with lower LLI. Conducting similar studies investigating a variety of different OwOb prevention methods would be valuable as well. For accurate results, known risk factors should be controlled for.

Strengths and Limitations

The availability of detailed prospective longitudinal data on a relatively large cohort is a major strength in this study; it allowed for optimal and efficient investigation of the association between overweight and obesity and childhood stature. Other studies that have investigated this relationship primarily used cross-sectional analyses. Cross-sectional analyses are satisfactory as a preliminary tool to formulate relevant hypotheses, however to accurately assess and develop prediction models, longitudinal data is essential. As such, this is a novel study conducted in the field of obesity and childhood anthropometry encompassing use of valuable longitudinal childhood data. The large sample sizes used for both the primary (n=1100) and secondary (n=544) analyses increased the power of this study implying that it is unlikely that the observed associations are spurious or due to chance alone.

Another strength of this study is that anthropometric variables were measured by trained professionals thereby avoiding recall bias from self-reported measurements. Nonetheless, this study may be subject to minor measurement error due to inter and intra-examiner measurement variability. However because the PHAST study employs strict variable measurement protocols and multiple measurements are taken for consistency, it is unlikely that these errors significantly affect the results.

A child's genetics plays an important role in determining overall stature, accounting for approximately 80% of the variation in their total growth (Jepson et al., 1994; Palmert & Hirschhorn, 2003). Therefore accurately accounting for the influence of genetics on the association between the leg length index and OwOb is imperative. This study accomplished this through controlling for maternal BMI. Many studies have utilized parental height and BMI to assess genetics, with the former used as an accurate indicator of a child's stature makeup and the latter as the child's genetic predisposition to OwOb. This has been shown as a fairly accurate method of accounting for genetics in epidemiological investigations, and is thus one of the major strengths in this study. Furthermore, this study used maternal measures which have been more strongly related to childhood growth than paternal measures (Wadsworth, 2002).

Using both body mass index and waist circumference to measure OwOb in epidemiological investigations has been deemed more appropriate than using either method alone due to the unique strengths and limitations each method encompasses (McCarthy, 2006). This study classified OwOb using BMI and used waist circumference to adjust for baseline adiposity. OwOb classification was done based on BMI since it is highly sensitive and is the more widely used and accepted measurement. The use of both indices in this study suggests the assessment of OwOb cases should be fairly accurate and unbiased. It should be noted however that more direct and accurate gold standard methods for measuring body adiposity are available (i.e. BodPod Analysis, Dual-Energy X-ray Absorptiometry) and should be employed for the most valid and reliable OwOb assessment.

These results provide strong evidence for the inverse association between LLI and childhood obesity, however a few limitations must be considered. One major limitation was that many secondary variables of interest (i.e. smoking status, birth weight, mother's age at birth, birth order) were self-reported, therefore the results could be subject to recall and information bias. The potential bias present here could partially account for the null relationships observed between early life experience factors and LLI in this study which were not consistent with previous studies. To overcome this impediment in future studies, more direct methods of obtaining this vital information should be employed, such as using birth certificates or records.

The results from this study may not be generalizable to the whole population of Niagara Regional children and adolescents. This is due to the narrow age range of the study sample which limits the generalizability of these results to only children and adolescents older than 8 years. Due to the drastically increasing OwOb prevalence observed in preschoolers and very young children today, research should be focused on a younger population of children as well.

The study results may also underestimate the true childhood OwOb burden in the Niagara Region. Almost half of the initial PHAST study sample was not included in the analysis due to incomplete anthropometric measurements. Although subjects who did and did not have complete information were similar in many aspects, it was observed that wave 3 subjects who did not provide complete information were notably fatter (higher waist circumference and BMI) than those that did provide complete data. Similarly, wave 8 subjects that did not have complete data also had higher waist circumference. However, they did not have a higher BMI which could be due to the fact that children have entered their pubertal growth period at that age and may have varying heights depending on their growth stage. Nevertheless, the significantly higher waist circumference observed in both waves indicates that subjects that did not have complete information did, to say the least, have higher abdominal adiposity than those who did provide complete data. This suggests that the true prevalence of OwOb in Niagara Region may actually be higher than reported in this study since data from many fatter children was missing, and thus not used in the analyses.

Another limitation to this study was the use of an indirect measure of leg length. The leg length was derived by subtracting sitting height from overall height (leg length= standing height- sitting height). This method of calculating leg length is criticized when used in populations with high prevalence of overweight and obesity (Bogin & Varela-Silva, 2008). Variations in an individual's subcutaneous buttocks fat (gluteo-femoral) increases sitting height which can consequently contribute to an artificial decrease in both leg length and leg length index (Bogin and Varela-Silva, 2008). An efficient method of measuring buttocks fat is assessing hip circumference, and further controlling for it in analyses, could have helped overcome the limitation. Although this study did not control for hip circumference, the baseline waist circumference was adjusted for since it is significantly correlated to hip circumference ($r=0.89$ $p<0.0001$). Therefore the above mentioned limitation should not be a significant issue in this study.

Nevertheless, future studies should directly measure leg length to obtain the most accurate estimate of relative leg growth.

Ethnicity was not investigated in this study. Variations in body composition including stature and adiposity do exist between children and adolescents of different ethnic backgrounds (Frisancho, 2007). Therefore future research should consider accounting for ethnicity in order to obtain an accurate depiction of the LLI-adiposity association as it exists among various ethnic groups. Investigating universal and consistent LLI cutoffs in child populations of varying demographics including different races, SES, age and gender would be worthwhile. If appropriate LLI cutoffs can be established in these diverse populations, an important early life OwOb screening tool may be developed for children.

Sleep deprivation was also not controlled for this study. Results from many studies on both children and adults have supported the inverse relationship between sleep hours and risk of obesity. Essentially, when an individual sleeps less than the recommended 7 or 8 hours, they become at higher risk for developing obesity (Prinz, 2004). Since the human body grows and develops at rest, the lack of sleep most likely affects their stature as well. Thus sleep hours could be a significant factor in the leg length index and obesity relationship and should be controlled for as a confounder.

Puberty is another important factor that affects both the child's body stature and adiposity. Many studies have noted early pubertal development in obese individuals, particularly in obese girls (Shalitin & Phillip, 2003). Because puberty wasn't controlled for in this study, it may be a limitation to the results.

Summary/Conclusion

The increasing burden of overweight and obesity in otherwise genetically stable populations such ours imply that environmental and social factors play a key role in the emerging obesity epidemic. Specifically, factors that affect normal growth and development in the child's critical growth periods have been noted to influence the risk of OwOb in adolescence and adulthood. The affects of these factors is directly reflected in the child's stature growth, or more importantly, in the amount of relative leg growth. Adverse factors retard normal growth and development contributing to lower relative leg growth and hence an increased risk of adiposity. The current study demonstrated a strong significant inverse association between leg length index, despite adjusting for many potential confounders. As such, the results from this study provide strong evidence for the utilization of LLI as an OwOb disease prediction tool. The three critical growth time periods identified by Dietz (1994) are the prenatal period, the early childhood adiposity rebound period (age 4-8 years) and adolescence. These are the essential periods in a child's life when development of adiposity may be initiated by factors that are known to influence it. Thus, the implementation of preventative strategies in these periods should be a primary step in battling the OwOb epidemic. To implement effective prevention efforts however, it is first crucial to clearly identify the OwOb risk factors. The current study examined the effect of many prenatal and early childhood factors on adolescence BMI and childhood leg length index. Interestingly, the results from this study suggested that maternal smoking could lower leg length index and increase risk of subsequent OwOb. Thus paediatric OwOb prevention efforts should directly target parental smoking prenatally, at birth and after birth in order to successfully lower the risk of harmful adiposity. Future research should be directed at evaluating the effects of other important childhood obesity risk factors on leg growth and development in critical growth periods.

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Appendix I

PARTICIPATION QUESTIONNAIRE

Name: ______________________________ Age: ______ years

Grade: ___________ Do you take Physical Education classes? YES / NO

INSTRUCTIONS:
In this survey you will be asked about the activities that you do at school and in your spare time. There are no right or wrong answers because this is not a test! Just answer each question as best as you can remember. Please read each question carefully before you answer it. TO ANSWER A QUESTION, JUST CHECK (✓) YOUR ANSWER OR PRINT YOUR ANSWER IN THE SPACE PROVIDED. Only select one answer for each question.

The following is a sample question to practice.

SAMPLE QUESTION

1. How often do you eat an apple?

Never	Once a month	Once a week
❑	❑	❑

SECTION 1: FREE TIME ACTIVITIES

This section asks questions about what you do during your free time. Some of the questions will be about recess, some about what you like to do after school, and others will be about what you do on weekends and holidays. Active games mean things like tag or skipping or playing catch.

1. During recess (or spares), do you spend most of your time:

Talk with my friends	Do school work	Play active games
❑	❑	❑

2. After school and before you eat supper, most of the time do you:

Watch television	Talk with my friends	Play active games	Play video games	Do other things (Specify below)
❑	❑	❑	❑	________

3. After supper and before you go to bed, do you spend most of your time:

Watch television	Talk with my friends	Read books	Play active games	Do other things (Specify below)
❑	❑	❑	❑	______________

4. On weekends, do you spend most of your time:

Watch television	Read	Play active games	Play video games	Talk with my friends	Do other things (Specify below)
❑	❑	❑	❑	❑	______________

5. During your free time, what are the three (3) things you like to do the most?

1. ____________________ 2. ____________________ 3.

6. During the summer, how often do you ride a bike? (If you answer never, go to Question #8)

Never	Once a month	Once a week	Once a day	All the time
❑	❑	❑	❑	❑

7. When you finish riding your bike, do you usually feel:

Very tired	Tired	A little tired	Not tired at all
❑	❑	❑	❑

8. During the winter, how often do you go ice skating for fun? (If you answer never, go to Question #10)

Never	Once a month	Once a week	Once a day	All the time
❑	❑	❑	❑	❑

9. When you finish ice skating, do you usually feel:

Very tired	Tired	A little tired	Not tired at all
❑	❑	❑	❑

10. How often do you go swimming for fun during the summer? (If you answer never, go to Question #12)

Never	Once a month	Once a week	Once a day	All the time
❑	❑	❑	❑	❑

11. When you have finished swimming, do you usually feel:

Very tired	Tired	A little tired	Not tired at all
❑	❑	❑	❑

12. During the winter, how often do you go cross-country skiing? (If you answer never, go to Question #14)

Never ❑ | Once a month ❑ | Once a week ❑ | Once a day ❑ | All the time ❑ ❑

13. When you finish cross-country skiing, are you usually:

Very tired ❑ | Tired ❑ | A little tired ❑ | Not tired at all ❑

14. If there are other activities that you do once a week or more, please list them below:

1. ______________________ 2. ______________________ 3.

15. How often do you watch television?

Every day ❑ | Almost every day ❑ | Hardly ever ❑ | Never ❑

16. How many hours per day do you usually watch television?

0-1 ❑ | 1-2 ❑ | 2-3 ❑ | 3-4 ❑ | 4-5 ❑ | 5 or more ❑

17. How often do you read a book in your free time?

Every day ❑ | Almost every day ❑ | Hardly ever ❑ | Never ❑

18. How many hours a day do you usually read books?

0-1 ❑ | 1-2 ❑ | 2-3 ❑ | 3-4 ❑ | 4-5 ❑ | 5 or more ❑

19. How often do you play video games in your spare time?

Every day ❑ | Almost every day ❑ | Hardly ever ❑ | Never ❑

20. How often do you play active games with your friends after school?

0-1 ❑ | 1-2 ❑ | 2-3 ❑ | 3-4 ❑ | 4-5 ❑ | 5 or more ❑

21. How often in a week do you play active games with your family?

Every day ❑ | Almost every day ❑ | Hardly ever ❑ | Never ❑

22. When you are playing active games with your friends or family, how often do you play hard enough to breathe heavily or make your heart beat quickly?

Very often ❑ Often ❑ Sometimes ❑ Hardly ever ❑ Never ❑

23. If you have daily or weekly chores at home (cutting grass, shoveling snow, farm chores, paper route), please list them below.

1. ___ 2. ______ 3. ______

24. How do you usually get to school?

Walk ❑ Ride a bike ❑ Take the bus ❑ Get a ride ❑

25. How long does it take you to get to school?

0-15 minutes ❑ 15-45 minutes ❑ more than 45 minutes ❑

26. How many older brothers do you have? ________________

27. How many older sisters do you have? ________________

28. How many younger brothers do you have? ________________

29. How many younger sisters do you have? ________________

SECTION 2: INTRAMURAL or HOUSE LEAGUE GAMES

. These are games like borden ball or volleyball that you play in teams at school. Only include active games. These do not include games you play in physical education classes, or recesses. **If you haven't played any intramural games this year, check this box ❑ and go directly to SECTION 3.**

30. How many different intramural (house-league) activities have you played this school year?

0 ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 or more ❑

(If you answered 0, please go directly to SECTION 3)

31. During your intramural games, how often did you have to work hard (breathing heavily, sweating, heart beating quickly):

Very often Often Sometimes Hardly ever Never

☐	☐	☐	☐	☐

32. After playing games in intramurals, are you usually:

Very tired	Tired	A little tired	Not tired at all
☐	☐	☐	☐

33. How many times a week, on average, do you play intramural games?

0	1	2	3	4	5 or more
☐	☐	☐	☐	☐	☐

34. How many hours each week do you think you spend playing intramural games at school?

0	1	2	3	4	5 or more
☐	☐	☐	☐	☐	☐

35. How many of your friends play intramural games?

Most of them	A few of them	None of them
☐	☐	☐

SECTION 3: SCHOOL SPORTS TEAMS

These questions are about school teams that play sports against teams from other schools. **If you don't play for any of your school's sports teams, check this box ☐ and go directly to SECTION 4.**

36. This school year, how many school sports teams have you belonged to?

0	1	2	3	4
☐	☐	☐	☐	☐

(If you answered 0, please go directly to SECTION 4)

37. After a game or practice, are you usually:

Very tired	Tired	A little tired	Not tired at all
☐	☐	☐	☐

38. During games or practices, did you have to work hard (breathing heavily, sweating, heart beating quickly):

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

39. How many hours per week do you usually spend in practices or games for school sports teams?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

40. How many of your friends play on school sports teams?

Most of them	A few of them	None of them
❑	❑	❑

SECTION 4: SPORTS TEAMS OUTSIDE OF SCHOOL

These are teams like hockey, ringette, soccer, and baseball in leagues that are not part of your school. **If you haven't played on any sports teams in the last year, check this box ❑ and go directly to SECTION 5.**

41. In the last year, how many sports teams have you played on?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

If you answered 0, go directly to SECTION 5)

42. How many times a week, on average, do you go to a practice or game?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

43. How many hours a week, on average, do you think you spend at practices and playing games for sports teams?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

44. During games and practices, did you have to work hard (breathing heavily, sweating, heart beating quickly):

Very often	Often	Sometimes	Hardly ever	Never
❑	❑	❑	❑	❑

45. After a practice or game, did you usually feel:

Very tired	Tired	A little tired	Not tired at all
❑	❑	❑	❑

46. How many of your friends play on sports teams?

Most of them ❑ A few of them ❑ None of them ❑

SECTION 5: SPORTS AND DANCE CLUBS

These are clubs like gymnastics, martial arts (karate, judo, etc.), tennis, golf, swimming, horseback riding, and dance (jazz, ballet, and tap). It doesn't include groups like Cubs or Girl Guides or 4H. **If you didn't belong to any sports or dance clubs in the last year, check this box ❑ and go directly to SECTION 6**

47. In the last year, how many DANCE clubs have you belonged to?

0 ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 or more ❑

48. In the last year, how many SPORTS clubs did you belong to?

0 ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 or more ❑

49. How many times a week, on average, do you go to a sport or dance competition or practice?

0 ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 or more ❑

50. How many hours a week, on average, do you think you spend at sport or dance activities?

0 ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5 or more ❑

51. During practices or competitions, how often did you have to work hard (breathing heavily, sweating, heart beating quickly):

Very often ❑ Often ❑ Sometimes ❑ Hardly ever ❑ Never ❑

52. How tired to you feel after a sport or dance competition or practice?

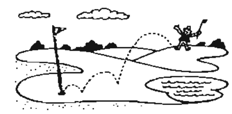
Very tired ❑ Tired ❑ A little tired ❑ Not tired at all ❑

53. How many of your friends belong to sports or dance clubs?

Most of them A few of them None of them

❑ ❑ ❑

SECTION 6: SPORTS AND DANCE LESSONS



This section asks questions about lessons that you took in the last year to learn things like swimming, tennis, golf, or dance. It also includes hockey schools. It doesn't include practices for teams or clubs. If you didn't take any sport or dance lesson in the last year, check this box ❑ and go directly to SECTION 7.

54. In the last year, how many different kinds of sports or dance lessons did you take?

0 1 2 3 4 5 or more

(If you answered 0, go directly to SECTION 7)

55. How many hours a week, on average, did you spend at sport or dance lessons?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

56. How many times a week did you go to a sport or dance lesson?

0	1	2	3	4	5 or more
❑	❑	❑	❑	❑	❑

57. How many of your friends take sport or dance lessons?

Most of them	A few of them	None of them
❑	❑	❑

58. During your sport or dance lessons, how often did you have to work hard (breathing heavily, sweating, and heart beating quickly):

Very often	Often	Sometimes	Hardly ever	Never
❑	❑	❑	❑	❑

SECTION 7: UNDERSTANDING YOUR

BODY

This section asks questions that will help us learn how much you understand about your body composition.

59. I think I weigh ______ pounds.

60. I think I am ______ feet _____ inches tall.

61. Check the answer that best describes how you feel about your body.

Very underweight	Somewhat underweight	Just the right weight	Somewhat overweight	Very overweight
❑	❑	❑	❑	❑

62. Check the answer that best describes how you would change your body.

Lose a lot of weight	Lose a little weight	Stay the same	Gain a little weight	Gain a lot of weight
❑	❑	❑	❑	❑

63. Check the answer that best describes how you like the way your body looks.

A lot	A little	Not at all	Hate how I look
❑	❑	❑	❑

THANK YOU VERY MUCH FOR COMPLETING THE PARTICIPATION QUESTIONNAIRE! ☺

Appendix II

PARENT'S QUESTIONNAIRE

The following questions will give us an idea of how you spend your time with your children (starting with less active things), your thoughts about their activity levels, and the challenges you face regarding their physical activity. Some questions will let us compare your answers to similar parents – age, gender, type of residence, etc. We would like the parent or guardian most familiar with your child to answer all questions.

Child's Name: ______________________

1. **Are you the child's:** Mother ☐ Father ☐ Legal guardian ☐

2. **How often do you read with your child?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

3. **How often do you talk to your child about what he/she is learning at school?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

4. **How often do you work with your child on school subjects each week?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

5. **How often do you review and discuss the completed work that your child brings home?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

6. **How often do you help your child with math?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

7. **How often do you do homework with your child?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

8. **How often do you watch television with your child?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

9. **How often do you play outside the house with your child?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

10. **How often do you play inside the house with your child?**
Never ☐ Once a month ☐ Once a week ☐ Once a day ☐ Always ☐

11. **How often do you ask your child about his/her progress in school?**

Never	Once a month	Once a week	Once a day	Always
☐	☐	☐	☐	☐

12. **How active are you in enrolling your son/daughter in sports?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

13. **How often do you go to your son/daughters sporting events with him/her (e.g., watch your son/daughter perform in a dance recital or at swim meets)?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

14. **How important is it to you to be actively involved in your son/daughter's sporting events?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

15. **How much do you enjoy participating in sport/physical activity?**

Very much	Quite a bit	Somewhat	A little bit	Not at all
☐	☐	☐	☐	☐

16. **How many times a week are you physically active for twenty minutes or more to the point where you are sweating and breathing hard?** _____ / week

17. **How frequently (on average) do you participate in sport/physical activity each week?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

18. **How often does your family use sport/physical activity as a form of family recreation (e.g., going on a bike ride together, hiking, ice skating)?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

19. **How much do you use your own actions to encourage your son/daughter to be physically active?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

20. **How often do time pressures interfere with you being able to help your child participate in sports or active play opportunities?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

21. **How often do financial constraints prevent you from helping your child participate in sports or active play opportunities?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

22. **How often do concerns about safety interfere with you allowing your child to be involved with sport or active play opportunities near your home?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

23. **How often to you wish there were more facilities for sport or active play closer to your home?**

Very often	Often	Sometimes	Hardly ever	Never
☐	☐	☐	☐	☐

24. How often do you find yourself just too tired to be involved in sports or active games with your child?
Very often ☐ Often ☐ Sometimes ☐ Hardly ever ☐ Never ☐

25. How often do any physical health problems you face make it difficult to be involved in sports or active games with your child?
Very often ☐ Often ☐ Sometimes ☐ Hardly ever ☐ Never ☐

26. I encourage my child to do physical activity and sports.
Never ☐ Rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Every day ☐

27. I participate in physical activity or sports with my child.
Never ☐ Rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Every day ☐

28. I provide transportation for my child to physical activity settings.
Never ☐ Rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Every day ☐

29. I watch my child being physically active or playing sports.
Never ☐ Rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Every day ☐

30. I tell my child when he/she is doing well in physical activities or sports.
Never ☐ Rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Every day ☐

31. I really want my child to do well at physical activities or sports.
Very false ☐ Mostly false ☐ Somewhat false ☐ Neutral ☐ Somewhat true ☐ Mostly true ☐ Very true ☐

32. I think my child is really good at physical activities or sports.
Very false ☐ Mostly false ☐ Somewhat false ☐ Neutral ☐ Somewhat true ☐ Mostly true ☐ Very true ☐

33. I think my child could do better at physical activities or sports.
Very false ☐ Mostly false ☐ Somewhat false ☐ Neutral ☐ Somewhat true ☐ Mostly true ☐ Very true ☐

34. I wish my child wanted to do better at physical activities or sports.
Very false ☐ Mostly false ☐ Somewhat false ☐ Neutral ☐ Somewhat true ☐ Mostly true ☐ Very true ☐

35. In general, would you say your child's health is:
Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor ☐

36. In your opinion, how physically active is your child compared to other children the same age and gender?
Much more ☐ Moderately more ☐ Equally ☐ Moderately less ☐ Much less ☐

How often would you say that your child:

37. **Can't sit still, is restless, or hyperactive?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

38. **Is distractible, has trouble sticking to any activity?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

39. **Fidgets?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

40. **Can't concentrate, can't pay attention for long?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

41. **Is impulsive, acts without thinking?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

42. **Has difficulty waiting turn in games or groups?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

43. **Gives up easily?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

44. **Cannot settle to anything for more than a few moments?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

45. **Stares into space?**
Never Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

46. **Is nervous, high-strung or tense?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

47. **Is inattentive?**
Never or not true ☐ Sometimes or somewhat true ☐ Often or very true ☐

48. **What ages are the children who live in your home? (Please list all!)**

Boy ________________ years **Girl** ________________ years
Boy ________________ years **Girl** ________________ years
Boy ________________ years **Girl** ________________ years
Boy ________________ years **Girl** ________________ years

Boy ________________ years **Girl** ____________________________
years

49. **What is the highest level of education that you have attained?** _ (Specify)

50. **What is your age?** _______ years

51. **What is your weight?** _______ pounds

52. **What is your height?** _______ feet _______ inches

53. **What do you think is your child's weight?** ______ pounds

54. **What do you think is your child's height?** _____ feet _____inches

55. **Do you live in an urban or rural dwelling?** Urban ☐
Rural ☐

56. **Do you own or rent your home?** Own ☐
Rent ☐

57. **Select the type of dwelling that best describes your home.**
   - ☐ Single detached house
   - ☐ Semi-detached
   - ☐ Low-rise apartment (less than 5 stories)
   - ☐ High-rise apartment (5 or more stories)
   - ☐ Other: _______________________ (Specify)

58. **What is your best estimate of your total family income before taxes and deductions from all sources during the past 12 months?**

   $__/__/__/__/__/__/

59. **What is your marital status?**
   - ☐ Now married
   - ☐ Common-law
   - ☐ Living with a partner
   - ☐ Single, never married
   - ☐ Widowed
   - ☐ Separated
   - ☐ Divorced

60. **Other than on special occasions (such as weddings, funerals or baptism), how often do you attend religious services or meetings?**

   Once a week ☐ Once a month ☐ 3 or 4 times a year ☐ Once a year ☐ Not at all ☐

61. **In what country were you born?**
   - ☐ Canada
   - ☐ Other ________________ (Specify)

62. **In which language(s) can you have a conversation?**
   - ☐ English
   - ☐ Other ________________ (Specify)

63. **What do you consider to be your main activity *during the past 12 months*? (MARK ONLY ONE)**
   - ☐ Caring for family
   - ☐ Working for pay or profit

- ☐ Caring for family & working for pay or profit
- ☐ Recovering from illness / on disability
- ☐ Other _________________________ (Specify)
- ☐ Going to school
- ☐ Looking for work
- ☐ Retired

Thank you for completing the Parent's Questionnaire. Please do not forget to return your entry draw form on the cover letter so that you are eligible for the raffle draw and your child's class can earn another pizza party courteous of Brock University.

Appendix III

Optimal Growth Study – Early Life Experience Questionnaire

INSTRUCTIONS: Please read questions carefully and try to answer as accurately as possible. This form ideally should be completed by the child's natural mother. If you are not the biological mother please check here ☐ and state your relation to the child________________ .

The following questions ask birth or after birth related information of (child name):________________.

1. Date of Birth: __ __(month) __ __ (day) __ __ __ __(yr).

2. Birth weight: ☐ grams ________, or ☐ lbs ___, oz_____.

3. How old were you (biological mother) when the child was born? _______(yrs).

4. Was the child born:

☐ Within a week of their due date
☐ One week early ☐ Two weeks early ☐ Three or more weeks early
☐ One week late ☐ Two or more weeks late

5. Was the child your first child?

☐ Yes ☐ Second child ☐ Third child ☐ Fourth or more.

6. How many kg/pounds did you gain during the pregnancy? _____(kg) or ______(lbs)

7. Please check if you (biological mother) were diagnosed or treated for any of the following during this pregnancy:

☐ High blood pressure ☐ Diabetes ☐ Anaemia ☐ Depression/anxiety

8. Was the child breast fed for:

☐ No breast fed ☐ Less than 1 month ☐ 1 – 3 months ☐ 3 – 6 months ☐ 6 or more months.

9. Do you presently smoke regularly (one of more cigarettes a day)? ☐ Yes ☐ No

10. Did you smoke regularly (one or more cigarettes a day) in the year <u>before</u> the pregnancy?

☐ Yes ☐ No (go to question 12)

11. Did you stop smoking when you learned you were pregnant?

☐ No (go to end) ☐ Yes, right away ☐ Within 1 month ☐ Within 2 months
☐ After 3 or more months

12. Did you smoke after giving birth of the child within the first year?

☐ No ☐ Yes, right away ☐ Within 1 month ☐ Within 2 months
☐ After 3 or more months

End of the questionnaire.

Appendix IV - Results from subjects with normal weight at baseline (N=902)

Table A1: Odds Ratios of OwOb predicted by LLI, Early Life Experience Factors and other childhood confounders.

	OwOb Prediction Models									
	OR	95% CI								
Variable	Model 1[b]		Model 2[b]		Model 3[b]		Model 4[a]		Model 5[b]	
LLI	0.898	0.766- 1.052	***0.752**	**0.573- 0.987**	***0.624**	**0.432- 0.900**	***0.555**	**0.366- 0.840**	***0.536**	**0.337- 0.854**
Birth Weight			0.916	0.684- 1.225	1.051	0.668- 1.654	0.944	0.585- 1.523	0.990	0.570- 1.717
Birth Order			1.190	0.777- 1.822	1.741	0.873- 3.472	***2.379**	**1.102- 5.136**	***2.727**	**1.198- 6.208**
Breastfeeding			0.881	0.520- 1.491	0.901	0.448- 1.811	0.842	0.395- 1.796	0.922	0.405- 2.095
Mother's BMI					1.030	0.914- 1.162	1.077	0.951- 1.219	1.034	0.903- 1.184
Mother's Age at Birth					0.889	0.784- 1.008	***0.829**	**0.713- 0.963**	***0.825**	**0.702- 0.970**
Parent's SS							0.747	0.323- 1.729	0.809	0.327- 2.005
Parent's Education							1.810	0.777- 4.215	1.101	0.415- 2.919
Physical Activity									0.950	0.863- 1.045
C-stat	**0.780**		**0.799**		**0.866**		**0.887**		**0.909**	

Abbreviation: LLI, Leg Length Index; SS, smoking status; c-stat, c-statistic
[a]Models also adjusted for baseline age, hip circumference and sex (excluding OwOb at baseline).
Note: Parent's SS refers to the overall smoking status

Table A2: Odds Ratios of OwOb predicted by Standing Height, Early Life Experience Factors and other childhood confounders.

Variable	Model 1[a]		Model 2[a]		Model 3[a]		Model 4[a]		Model 5[a]	
	OwOb Prediction Models									
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Standing Height	***0.912**	**0.869- 0.956**	0.946	0.876- 1.022	0.921	0.827- 1.025	0.913	0.819- 1.017	***0.856**	**0.755- 0.972**
Birth Weight			0.930	0.696- 1.242	1.012	0.654- 1.566	0.949	0.600- 1.501	1.027	0.596- 1.770
Birth Order			1.167	0.763- 1.785	1.860	0.955- 3.623	***2.337**	**1.124- 4.862**	***2.750**	**1.240- 6.099**
Breastfeeding			0.881	0.521- 1.488	0.899	0.454- 1.776	0.904	0.431- 1.898	1.085	0.475- 2.481
Mother's BMI					1.042	0.932- 1.165	1.075	0.957- 1.208	1.026	0.900- 1.170
Mother's Age at Birth					***0.874**	**0.769- 0.994**	***0.834**	**0.720- 0.967**	***0.825**	**0.700- 0.973**
Parent's SS							0.976	0.457- 2.083	0.987	0.410- 2.373
Parent's Education							2.045	0.899- 4.651	1.180	0.462- 3.016
Physical Activity									0.964	0.877- 1.059
C-stat	**0.805**		**0.790**		**0.841**		**0.847**		**0.883**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a] Models also adjusted for baseline age, hip circumference and sex
Note: Parent's SS refers to the overall smoking status

Table A3: Odds Ratios of OwOb predicted by Sitting Height, Early Life Experience Factors and other childhood confounders.

Variable	OwOb Prediction Models OR 95% CI Model 1[a]		Model 2[a]		Model 3[a]		Model 4[a]		Model 5[a]	
Sitting Height	***0.896**	**0.825- 0.974**	1.018	0.882- 1.175	1.074	0.899- 1.283	1.091	0.896- 1.328	0.994	0.785- 1.258
Birth Weight			0.908	0.680- 1.214	0.990	0.642- 1.526	0.907	0.575- 1.430	0.962	0.569- 1.624
Birth Order			1.218	0.800- 1.854	***1.964**	**1.016- 3.798**	***2.466**	**1.190- 5.109**	***2.733**	**1.273- 5.871**
Breastfeeding			0.846	0.501- 1.430	0.846	0.427- 1.678	0.843	0.403- 1.765	0.972	0.432- 2.186
Mother's BMI					1.047	0.938- 1.170	1.085	0.968- 1.217	1.038	0.918- 1.174
Mother's Age at Birth					***0.871**	**0.768- 0.988**	***0.833**	**0.721- 0.964**	***0.824**	**0.704- 0.967**
Parent's SS							0.980	0.457- 2.103	1.052	0.450- 2.457
Parent's Education							1.776	0.791- 3.985	1.217	0.494- 2.999
Physical Activity									0.959	0.872- 1.055
C-stat	**0.788**		**0.770**		**0.818**		**0.835**		**0.854**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a] Models also adjusted for baseline age, hip circumference and sex
Note: Parent's SS refers to the overall smoking status

Table A4: Odds Ratios of OwOb predicted by Leg Length, Early Life Experience Factors and other childhood confounders.

Variable	Model 1[a] OR	Model 1[a] 95% CI	Model 2[a] OR	Model 2[a] 95% CI	Model 3[a] OR	Model 3[a] 95% CI	Model 4[a] OR	Model 4[a] 95% CI	Model 5[a] OR	Model 5[a] 95% CI
Leg Length	***0.898**	**0.842- 0.957**	***0.899**	**0.810- 0.999**	***0.837**	**0.724- 0.967**	***0.821**	**0.708- 0.951**	***0.778**	**0.655- 0.923**
Birth Weight			0.933	0.698- 1.249	1.061	0.674- 1.670	0.983	0.613- 1.577	1.029	0.590- 1.795
Birth Order			1.156	0.753- 1.773	1.732	0.872- 3.441	***2.297**	**1.076- 4.902**	***2.750**	**1.202- 6.292**
Breastfeeding			0.894	0.529- 1.511	0.922	0.463- 1.837	0.893	0.421- 1.898	1.030	0.451- 2.450
Mother's BMI					1.035	0.922- 1.162	1.073	0.951- 1.212	1.027	0.898- 1.176
Mother's Age at Birth					0.884	0.778- 1.005	***0.831**	**0.715- 0.966**	***0.825**	**0.699- 0.974**
Parent's SS							0.839	0.376- 1.875	0.864	0.347- 2.146
Parent's Education							2.052	0.885- 4.759	1.133	0.428- 2.998
Physical Activity									0.955	0.869- 1.050
C-stat	**0.800**		**0.800**		**0.858**		**0.870**		**0.901**	

Abbreviation: SS, smoking status; c-stat, c-statistic
[a] Models also adjusted for baseline age, hip circumference and sex
Note: Parent's SS refers to the overall smoking status