The role of physical activity, obesity and perception of weight status in the prevention of elevated blood pressure in youth: biological and behavioral investigations

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Abstract

Background: Effective interventions to prevent obesity in youth are needed in order to alleviate the public health burden associated with elevated blood pressure (BP). However, interventions designed to prevent obesity through increased physical activity levels have had limited success.

Objectives: This thesis has four objectives: 1) to assess the impact of changes in adiposity indicators on increases in systolic blood pressure (SBP) during adolescence; 2) to examine the longitudinal association between declines in physical activity and SBP in youth; 3) to assess whether weight status misperception is associated with exposure to overweight/obese people at home or in school; 4) to examine if weight status misperception is associated with the level of participation in physical activity.

Methods: SBP and anthropometry were assessed biannually (1999/2000, 2002, 2004) in a cohort of 1293 Montréal adolescents aged 12-13 years in 1999. Self-report 7-day recalls of physical activity sessions ≥5 minutes were collected every three months over five years. The repeated SBP measurements were analyzed using individual growth models to assess the effect of changes in adiposity indicators on SBP change. Estimates of initial level and rate of decline in number of physical activity sessions per week from individual growth models were used as predictors of BP in linear regression models to assess the effect of declines in physical activity on BP. The hypotheses that youth exposed to obesity at home and in school are more likely to underestimate their weight status, and that those who underestimate their weight status are less likely to engage in physical activity were tested in a provincially representative, school-based sample of 3665 youth (age 9, n = 1267; age 13, n = 1186; age 16, n = 1212). Multi-level linear regression models were used to assess the association between parent and schoolmate BMI, and weight status misperception (i.e., the standardized difference between self-perception of weight status and actual weight status). Poisson regression models were used to assess the association between weight status misperception and physical activity.

Results: 1) Despite sex differences in mean SBP changes, the magnitude of the effect of one unit change in each adiposity indicator on SBP change was similar in boys and girls. 2) Physical activity declined during adolescence and a decline of one physical activity session per week with each year of age was associated with higher BP. 3) Majority of overweight youth underestimated their weight status. Higher parent and schoolmate BMI were associated with greater weight status underestimation. 4) Youth who underestimated their weight status were less likely to engage in physical activity.

Conclusion: These findings support the need for interventions to prevent excess weight and physical inactivity during adolescence to prevent higher BP in youth. Weight status misperception may reduce motivation among youth to engage in physical activity, and therefore hinder the success of obesity prevention interventions.

Résumé

Problématique : Des interventions efficaces sont nécessaires pour prévenir l'obésité chez les jeunes afin de réduire le fardeau en santé publique associé à la tension artérielle elevée. Par contre, le succès des interventions ayant pour but la prévention de l'obésité par l'augmentation de l'activité physique a été limité dans le passé.

Objectifs : Ce mémoire a quatre objectifs : 1) évaluer l'impact des changements d'indices d'adiposité sur l'augmentation de la tension artérielle systolique à l'adolescence; 2) examiner les associations longitudinales entre le déclin d'activité physique et la tension artérielle systolique chez les jeunes; 3) évaluer si la perception erronée du statut pondéral chez les jeunes est associée à l'exposition aux personnes avec surpoids ou obésité à la maison ou à l'école; 4) examiner si la perception erronée du statut pondéral est associée au niveau d'activité physique.

Méthodes : La tension artérielle systolique et des mesures anthropométriques furent évaluées de façon biannuelle (1999/2000, 2002, 2004) au sein d'une cohorte de 1293 adolescents de Montréal âgés de 12 à 13 ans en 1999. Un questionnaire auto-administré de rappel des activités physiques de plus de 5 minutes des sept derniers jours fut rempli à tous les trois mois pendant cinq ans. Les mesures répétées de la tension artérielle systolique ont été analysées par des modèles de croissance individuelle afin d'évaluer l'effet des changements des indices d'adiposité sur la tension artérielle systolique. L'effet du déclin de l'activité physique sur la tension artérielle fut estimé par des modèles de régressions linéaires utilisant des modèles de croissance individuelle du niveau initial et du taux de réduction d'activité physique. Les hypothèses selon lesquelles les jeunes exposés à l'obésité à la maison et à l'école ont plus tendance à sous-estimer leur statut pondéral, et que ceux qui sous-estiment leur statut pondéral auront moins tendance à pratiquer de l'activité physique furent testées dans une enquête en milieu scolaire auprès d'un échantillon provincial représentatif de 3665 jeunes âgés de 9 (n = 1267), 13 (n = 1186), et 16 ans (n = 1212). Des modèles multiniveaux de régression linéaire ont été utilisés pour évaluer l'association entre l'indice de masse corporelle des parents et des pairs et la perception erronée du statut pondéral (c'est-à-dire la différence standardisée entre la perception du statut pondéral et le statut pondéral réel). Les modèles de régressions de Poisson ont été utilisés pour examiner l'association entre la perception erronée du statut pondéral et l'activité physique.

Résultats : 1) Malgré une différence selon le sexe de la moyenne des changements de tension artérielle systolique, chaque unité de changement d'indice d'adiposité avait un effet similaire sur la variation de tension artérielle systolique chez les garçons et les filles. 2) L'activité physique a diminué pendant l'adolescence. La réduction d'une session d'activité physique par semaine par année de vie était associée à une augmentation de la tension artérielle. 3) La plupart des jeunes avec un surplus de poids sous-estimaient leur statut pondéral. Un indice de masse corporelle plus élevé chez les parents et les pairs était associé à une plus grande sous-estimation du statut pondéral chez les jeunes. 4) Les jeunes qui sous-estimaient leur statut pondéral étaient moins actifs physiquement.

Conclusion : Ces résultats confirment le besoin d'intervenir au niveau des problématiques que sont l'excès de poids et l'inactivité physique à l'adolescence,

afin de prévenir l'élévation de la tension artérielle systolique chez les jeunes. La perception erronée du statut pondéral peut réduire la motivation des jeunes quant à l'activité physique. Ceci aura tendance à diminuer le succès des interventions visant à contrer l'obésité.

Abbreviations

ARYA	Atherosclerosis Risk in Young Adults
BMI	Body mass index, kg/m^2
BP	Blood pressure, mmHg
CATCH	Child and Adolescent Trial for Cardiovascular Health
CDC	Centers for Disease Control and Prevention
CHD	Coronary heart disease
CI	Confidence interval
cIMT	Carotid intima media thickness
CRCHUM	Centre de recherche du Centre hospitalier de l'Université de Montréal
CVD	Cardiovascular disease
DBP	Diastolic blood pressure, mmHg
DISC	Dietary Intervention Study in Childhood
DXA	Dual-energy X-ray absorptiometry
ECG	Echocardiography
GEE	Generalized estimating equations
H.S.	High school
ICC	Intra-class correlation
LVM	Left ventricular mass
MET	Metabolic equivalent
mmHg	Millimetre of mercury
MVPA	Moderate-to-vigorous physical activity

NDIT	Nicotine Dependence in Teens Study
NHANES	National Health and Nutrition Examination Survey
No.	Number
ns	Not significant
OR	Odds ratio
PAR	Population attributable risk
PDAY	Pathobiological Determinants of Atherosclerosis in Youth
QCAHS	Québec Child and Adolescent Health and Social Survey
SD	Standard deviation
SE	Standard error
SES	Socioeconomic status
SBP	Systolic blood pressure, mmHg
WCH	"White coat" hypertension

Contributions of Authors

I had the original research ideas for all four manuscripts included in this thesis. I extracted the data from the Nicotine Dependence in Teens (NDIT) Study and the Québec Child and Adolescent Health and Social (QCAHS) Survey databases. I conceived and carried out all statistical analyses and wrote the first draft of each manuscript. The contributions of co-authors to each of the four manuscripts included in this thesis are described below.

Manuscript #1

Title: The impact of changes in anthropometric characteristics on blood pressure during adolescence

The manuscript is under review in the journal *Epidemiology.*

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Jennifer O'Loughlin, PhD: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and reviewed drafts of the manuscript.

Gilles Paradis, MD MSc, FRCPC: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and reviewed drafts of the manuscript.

James Hanley, PhD: Assisted with statistical analyses, interpretation of the findings, and manuscript development.

John Lynch, PhD: Assisted in conceptualizing the design, the study variables and the analysis, interpretation of the results and reviewed drafts of the manuscript.

Manuscript #2

Title: Declines in physical activity and higher systolic blood pressure in adolescence

The manuscript is accepted for publication in the *American Journal of Epidemiology.*

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James Hanley, PhD: Assisted with statistical analyses, interpretation of the findings, and manuscript development.

John Lynch, PhD: Assisted in conceptualizing the design, the study variables and the analysis, interpretation of the results and reviewed drafts of the manuscript.

Manuscript #3

Title: Do you see what I see? Weight status misperception and exposure to obesity among children and adolescents

This manuscript is accepted for publication in the *International Journal of Obesity*.

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Jennifer J. McGrath, PhD: Assisted in conceptualizing the design, the study variables and the analysis, and participated in writing the manuscript.

Tracie Barnett, PhD: Assisted with statistical analyses, interpretation of the findings, and manuscript development.

Jennifer O'Loughlin, PhD: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and reviewed drafts of the manuscript.

Gilles Paradis, MD, MSc, FRCPC: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and reviewed drafts of the manuscript.

Marie Lambert, MD: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and reviewed drafts of the manuscript.

Manuscript #4

Title: Youth who underestimate their weight status engage in less physical activity

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James A. Hanley, PhD: Assisted with statistical analyses, interpretation of the findings, and manuscript development.

Marie Lambert, MD: Designed the original study from which the data were drawn, obtained funding for the original study, supervised data collection and developing research hypotheses.

John Lynch, PhD: Assisted in conceptualizing the design, the study variables and the analysis, interpretation of the results and reviewed drafts of the manuscript.

Statement of originality

The four manuscripts presented in this thesis constitute original research. Each of the four manuscripts makes an original contribution to cardiovascular research in youth. The research questions in the first and second manuscripts were addressed using rigorous methodological approaches for longitudinal data. The results of these two manuscripts have shown that weight gain and declines in physical activity during adolescence have a detrimental effect on BP in youth, highlighting the need for effective interventions at the population level to prevent excess weight gain and declines in physical activity in childhood and adolescence. To the best of our knowledge, the research questions in the third and fourth manuscripts had not been previously studied. The results of the third manuscript have shown that youth often do not judge their weight status accurately, particularly when they live in obesogenic environments. Weight status misperception may be an important component of prevention interventions aimed at modifying lifestyle behaviours such as physical activity. This is because the results of the fourth manuscript have shown that youth who do not perceive their weight status accurately are less likely to engage in physical activity. Although the data used in this thesis were not collected to specifically study blood pressure, obesity and physical activity in youth, these data were nevertheless well suited to address the research questions in the four manuscripts.

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Chapter 1: Introduction

Cardiovascular diseases (CVD) are the major causes of morbidity and mortality in both developed and developing countries.(1) An estimated 17.5 million people die from CVD each year, representing one in every three deaths worldwide.(2, 3) In Canada, CVD is the leading cause of death, and 36 percent of all deaths in 1999 were due to CVD-related causes.(4) Yet, as much as 80 percent of CVD can be prevented by maintaining a healthy body weight, engaging in regular physical activity, having a healthy diet, and not smoking.(3, 5)

Elevated blood pressure (BP) is one of the most important modifiable risk factors for CVD.(1) It is the leading cause of the global burden of disease, including coronary/ischemic heart disease, congestive heart failure, stroke and renal disease.(6) Worldwide, two-thirds of stroke and one-half of ischemic heart disease among adults are attributable to elevated BP, and these proportions are even higher in developed countries.(6, 7) Each year, an estimated 7.1 million deaths worldwide are due to elevated BP in adults, representing 13 percent of all deaths.(6) Many epidemiological studies demonstrate a continuous gradient in the association between elevated BP in adulthood and increased risk of CVD morbidity and mortality,(8, 9) such that even relatively small increases in BP can have a substantial impact on CVD morbidity and mortality.(1, 6) Prevention and management of elevated BP are therefore critical to reducing the burden of CVD.(10)

The prevalence of several CVD risk factors declined substantially over the last few decades.(11, 12) According to the U.S. National Health and Nutrition Examination Surveys (NHANES), the prevalence of elevated BP declined from 31 percent to 15 percent between 1960-1962 and 1999-2000, of elevated cholesterol from 34 percent to 17 percent, and of smoking from 39 percent to 26 percent.(11) Despite these encouraging trends, the prevalence of these CVD risk factors remains high among adult populations, with every sixth person having elevated BP or elevated cholesterol, and every fourth person being a smoker. The prevalence of overweight and obesity among US and Canadian adults also increased dramatically in recent decades, such that one-third of adults in the US and Canada is either overweight or obese.(13, 14)

While CVD becomes manifest only in adulthood, there is good evidence that the etiology of CVD and the accompanying atherosclerotic process begins in childhood.(15, 16) Elevated BP in youth promotes the atherosclerotic process, characterized by fatty streaks and plaque deposits in the intima of major arteries.(17-19) Several major studies have also established the relationship between elevated BP and surrogate markers of CVD in childhood, such as coronary artery calcification, increased left ventricular mass, and carotid artery intima-media thickness.(16, 18, 20-23) The size of the left ventricular mass increased continuously with BP percentiles in normotensive children,(24-26) and a high prevalence of left ventricular hypertrophy has been found among hypertensive youth.(20, 21) Elevated BP in early life is therefore a putative risk factor for CVD development later in life.(27) Indeed, BP levels in adolescence and young adulthood are independent predictors of CVD risk later in life, indicating that the etiology of CVD begins early in the lifecourse.(28)

BP also tracks from childhood to adulthood,(29) indicating that children with elevated BP are more likely to have elevated BP in adulthood. The degree of BP tracking is relatively high such that children remain within the same BP quartiles from early childhood through adolescence.(29) Moreover, individuals who maintain elevated BP levels from childhood to adolescence have the thickest carotid intima later in adulthood.(30) Elevated BP in early life is, therefore, of concern because the course of BP change may be set early in life, indicating that BP in childhood and adolescence is an excellent marker for predicting adult BP and CVD risk later in life.(31)

Obesity is strongly related to BP in youth,(32, 33) and a positive association between BP and excess weight in youth exists across the entire body mass index (BMI) distribution with no obvious threshold in risk.(33) Maintaining a healthy body weight and engaging in regular physical activity are considered to be cornerstones of the prevention of elevated BP in youth.(34) The prevalence of childhood obesity increased almost threefold since the 1980s,(35, 36) reaching epidemic levels in Canada and worldwide.(37) In Canada, 26 percent of 2-17 year olds were overweight or obese in 2004 compared with 15 percent in 1978/1979.(38) Obesity is a risk factor for CVD and is associated with increased left ventricular mass and thicker carotid intima-media in youth. It has been found to accelerate the atherosclerotic process in adolescence and young adulthood.(39, 40) Similar to BP, childhood obesity tracks into adulthood.(41-43)

Since excess weight is a risk factor for elevated BP, the increasing prevalence of obesity in children and adolescents has stimulated concern about BP in youth. BP levels are believed to increase concomitantly with obesity levels in youth, leading to an increased prevalence of elevated BP in youth.(44, 45) Overall, the evidence suggests that the risk for CVD develops gradually beginning in childhood or adolescence. This underscores the importance of primary prevention of CVD risk factors starting at an early age. The importance of BP in early life and the impact of obesity on BP development suggest the need for a particular emphasis on preventing excess weight gain during childhood and adolescence to prevent elevated BP, and CVD risk later in life.

Maintaining a healthy body weight and engaging in regular physical activity are recommended for the prevention and management of obesity,(46, 47) and elevated BP in youth.(34) Although weight loss through increased physical activity led to decreases in BP in clinical populations of overweight and obese, or hypertensive youth, obesity prevention interventions designed to increase physical activity levels in non-clinical populations of youth and for longer periods of time have had limited success.(48-50) In a recent Cochrane review of 22 randomized controlled trials, Summerbell et al. (2005) reported that childhood obesity prevention interventions resulted in no reduction of overweight and only modest improvements in physical activity behaviours in the short-term.(50) The key to effectiveness and sustainability of obesity prevention is long-term adherence to increased levels of physical activity,(51) but healthy lifestyle behaviour is difficult to sustain in the long-term.

Since the prevalence of childhood obesity is reaching epidemic levels in Canada and worldwide, and there is a high prevalence of physical inactivity among youth, substantial efforts are required to prevent obesity and physical inactivity in youth in order to alleviate the public health burden of CVD associated with elevated BP.(10, 52) The general objectives of this thesis are two-fold; it aims to improve understanding of (1) the role of the changes in physical activity and obesity that occur during adolescence on BP in youth, and (2) the possible barriers to preventive efforts to reduce overweight and obesity and improve physical activity levels in youth. Adolescence is particularly well-suited for the study of this relationship since it is a period of rapid growth and behavioural changes when BP, height, weight and body fat increase rapidly (53, 54) and physical activity levels decline sharply.(55-57) The general theoretical framework in Figure 1.1 depicts development of CVD as a result of unhealthy lifestyle patters, such as physical inactivity and excess energy intake, which are rooted in unfavourable social and economic conditions. Obesity contributes to the development of elevated blood pressure and accelerates the effects of other factors.

FIGURE 1.1. Theoretical framework of development of cardiovascular disease

Chapter 2: Literature review

This literature review provides a summary of the current state of knowledge on BP and obesity prevention efforts in youth. I begin with a discussion of the importance of BP and obesity for the development of CVD later in life. This is followed by an overview of the definition, prevalence, tracking, BP increases with age and measurement of BP, as well as methodological challenges in studying BP in youth. I then discuss the literature on the management of elevated BP and obesity in clinical populations of youth, and prevention of elevated BP and obesity in non-clinical populations of youth, as well as methodological challenges in studying these associations. Last, I discuss the challenges in modifying lifestyle behaviours in the long run to prevent weight gain and physical inactivity in youth, with an overview of behaviour modification theories.

Cardiovascular disease and atherosclerotic process

While CVD becomes manifest only in adulthood, there is good evidence that the etiology of CVD and the underlying atherosclerotic process begin in childhood. Autopsy studies demonstrated the presence of fatty streaks and plaque deposits (i.e., atherosclerotic lesions in the aorta and coronary arteries) in youth. The Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study was a multicenter in 14 forensic laboratories that autopsied arteries and other tissue from 3,000 young persons aged 15 to 34 years who died as a result of accidents, homicides, and suicides or other external causes.(58) PDAY data demonstrated that the extent of fatty streaks and plaque deposits in coronary arteries was associated with BP, BMI and other modifiable risk factors obtained from clinical charts, suggesting that the effects of BP and BMI on the atherosclerotic process begins in childhood and adolescence.(18, 59) The extent of atherosclerosis in the aorta and coronary arteries was also examined in the Bogalusa Heart Study, using data from 204 young persons aged 2 to 39 years who died of injuries or other causes and were autopsied. Berenson et al. (1998) reported that the extent of fatty streaks and fibrous plaques in the aorta and coronary arteries was strongly associated with SBP, DBP, and BMI measured before death.(15)

Several studies have used echocardiography (ECG), ultrasound, and other diagnostic methods to study the association between BP and early markers of atherosclerosis, such as left ventricular mass (LVM), carotid intima media thickness (cIMT), and coronary artery calcification in youth. A high prevalence of left ventricular hypertrophy (41 percent) and increased cIMT (28 percent) has been reported in children with elevated BP.(20) Moreover, the size of LVM was positively associated with SBP across the entire SBP distribution in 654 healthy youth aged 7 to 22 years in the Bogalusa Heart Study, indicating a continuous relationship without an obvious threshold in risk, even after adjustments for BMI.(24) In the Muscatine Study, both LVM (measured by ECG) and BP tracked in 274 children aged 6 to 15 years over 3.4 years of follow-up (r=0.33 and 0.44).(60) In addition, SBP was an independent predictor of LVM in a cross-sectional analysis of 124 children aged 8 to 12 years from the Muscatine Study.(25) In another report on 264 school children from the Muscatine Study, LVM was significantly greater in children with BP in the upper quintile compared with those in the lower BP quintiles, after adjustments for BMI and triceps skinfold thickness.(61)

The Muscatine Study also reported on the association between SBP and BMI measured at ages 15, 27 and 33 years and coronary artery calcification in 384 young adults aged 33 years. The odds ratio (OR) for coronary artery calcification in the highest decile of BMI was 6.4 in men and 13.6 in women. In the highest decile of SBP, the ORs were 6.4 in men and women, respectively.(16) The Cardiovascular Risk in Young Finns study is an ongoing longitudinal study that follows every 3 years a cohort of 3,596 children aged 3 to18 years at baseline. Viikari et al. (2004) showed that elevated BP and increased body weight in childhood contributed to the development of atherosclerosis among 2264 subjects followed up to age 24 to 39 years.(62) The Bogalusa Heart Study, which assessed 835 children four or more times over 26.5 years of follow-up, reported that SBP in childhood and adolescence was a consistent predictor of arterial stiffness at ages 24 to 44 years.(63)

Although early studies of the relationship between cIMT and elevated BP were confounded by obesity, more recent studies have demonstrated that these associations were independent of obesity. A recent case-control study by Lande et al. (2006) demonstrated that BP was related to cIMT in youth, independent of overweight and obesity. The median cIMT in hypertensive youth was significantly greater than that in normotensive controls matched for age, gender and BMI (0.67 vs. 0.63 mm).(21)

Obesity is known to accelerate the progression of atherosclerosis in youth. In the PDAY study, McGill et al. (2002) found that obesity was associated with accelerated coronary atherosclerosis in adolescent and young adult men.(39) In the Bogalusa Heart Study, 486 adults aged 25 to 37 years were assessed at least 3 times since childhood. Li et al. (2003) reported significant associations between both SBP and BMI in childhood and cIMT in adulthood. Childhood BMI was a significant predictor for being in the top vs. the lower 3 quartiles of cIMT (OR=1.25), after adjusting for BP.(64) Another analysis of data from the Bogalusa Heart Study showed that BMI in childhood and adulthood was related to cIMT at age 36 years in 1142 participants.(65) In the Cardiovascular Risk in Young Finns Study, elevated SBP and excess weight in youth were significantly associated with increased cIMT and decreased carotid artery elasticity in adulthood.(40) Moreover, BP tracking was associated with the development of atherosclerosis in young adulthood. In the Atherosclerosis Risk in Young Adults (ARYA) study, youth who maintained elevated BP levels from adolescence to adulthood had the thickest cIMT later at age 30 years.(30)

The correlations of LVM and BMI were r=0.38 at 13 years and r=0.55 in a convenience sample of 132 healthy youth aged 27 years, and the rate of increase in BMI between 13 and 27 years was associated with the increase in LVM from childhood to young adulthood, independent of BMI at 13 years.(66) In the

Bogalusa Heart Study, 467 subjects were examined 6 times over a follow-up of 21.5 years from childhood until the age of 20 to 38 years. The cumulative effects of BMI and SBP from childhood to adulthood were significant and consistent predictors of LVM in young adulthood.(67) In addition to SBP and DBP, body weight had a strong positive association with LVM (measured by ECG) in a cross-sectional analysis of 904 children aged 6 to 16 years from the Muscatine Study.(26)

The studies reviewed in this section indicate that the etiology of CVD begins early in life, with elevated BP and obesity during childhood and adolescence being important risk factors for CVD risk later in life. They underscore the potential for prevention of obesity from an early age to help alleviate the CVD burden associated with elevated BP in adulthood.

What is blood pressure?

BP is defined as the force or pressure of blood applied to the arterial walls. SBP refers to pressure on the arterial walls when the heart contracts to pump blood to the body; DBP refers to pressure when the heart relaxes between beats. BP is the driving force that moves blood through the vascular system to provide an adequate supply of blood from the heart to body organs and tissues, that require a steady, continuous blood flow for metabolic activity and to sustain life. Thus, BP plays a central role in the functioning of key body organs, such as the brain, and it maintains whole body homeostasis.

Physiological regulation of BP is complex and involves interplay between cardiovascular, renal, neural, and endocrine systems. Although the mechanisms responsible for BP development in youth are currently not well understood,(68, 69) it is believed that obesity promotes elevated BP through an increase in the sympathetic nervous activity, insulin resistance and arterial stiffness – all of which increase cardiac output and systemic vascular resistance.(70, 71) Insulin resistance, a state in which the tissues are less sensitive to insulin and require the pancreatic cells to work harder to overcome this resistance, increases BP by leading to a hyperinsulinemic state, which ultimately increases CVD risk.(72, 73)

Weight loss improves insulin sensitivity and sympathetic nervous activity, and decreases cardiac output and systemic vascular resistance,(74-76) promoting restoration of normal BP levels in obese youth.(68) Physical activity, defined as any body movement achieved by contraction of skeletal muscles that increase energy expenditure above resting levels, affects BP through increasing energy expenditure and promoting weight loss.(77) In addition to an indirect effect on BP through weight loss, physical activity may also have a direct effect on BP, independent of weight loss, through improvements in insulin resistance, and reductions in sympathetic nervous activity and systemic vascular resistance.

Prevalence of elevated blood pressure

Sex, age and height are the main determinants of BP levels in youth.(34) The definition of elevated BP in children and adolescents under age 18 years is sex, age, and height-specific since it is based on a distributional/statistical approach of percentile cut-offs specific for sex, age, and height. Normal BP is defined as SBP or DBP below the 90th percentile of the distribution specific to sex, age and height. Elevated BP (hypertension) is defined as SBP or DBP at or above the 95th sex-, age-, and height-specific percentiles on at least 3 measurement occasions. This conceptualization of hypertension designates that by definition about 5 percent of children and adolescents have elevated BP (though they may not be diagnosed with it). BP levels at or above the 90th but below the 95th percentiles are considered pre-hypertensive or at risk of hypertension.(34)

Among Québec youth, the prevalence of borderline or elevated SBP (i.e., SBP at or above sex-, age-, and height-specific 90th percentile) at ages 9, 13, and 16 years was 12 percent, 22 percent and 30 percent in boys and 14 percent, 19 percent and 17 percent in girls in 1999.(32) Dramatic increases in the prevalence of childhood and adolescent obesity are believed to lead to corresponding increases in the prevalence of elevated BP in youth, since excess weight is a risk factor for elevated BP.(78) Several recent studies demonstrated that BP levels increased concomitantly with obesity levels in youth, leading to an increased prevalence of elevated BP.(44, 45) For example, a review of BP data in 8 to 17 year old children from NHANES and other national surveys in the USA between 1963 and

2002, Din-Dzietham et al. (2007) examined secular trends in elevated BP and obesity, and found that although the prevalence of elevated BP in youth declined between 1963 and 1988, it increased by 3.3 percent between 1988 and 1999. The authors attributed this increase to increases in the prevalence of childhood obesity.

However, there is no consensus on whether there is a relationship between BP and obesity in youth at the population level. Studies on the prevalence or incidence of elevated BP in children and adolescents are limited, and it is difficult to compare across studies since BP varies depending on the measurement technique, device used to measure BP, study setting, number of readings, child position,(79) and in addition, there is no consensus on criteria to define and measure BP in youth.(80) For example, in a survey of 708 pediatricians, Lip et al. (2001) showed that the criteria for diagnosing a child as hypertensive varied greatly among pediatricians who based it on SBP alone (18 percent), DBP alone (13 percent) or both (66 percent). They also used either 90^{th} (13 percent), 95^{th} (42 percent) or higher (45 percent) percentiles as the cutoff value. Thus, the measurement of pediatric BP is inconsistent across studies and the diagnosis of pediatric hypertension is unstandardized.(80)

A recent review on secular trends in BP and obesity in youth limited to studies that used identical BP measurement and diagnostic criteria found that despite rising obesity levels, there was little evidence that BP increased in the population, suggesting that obesity may not directly relate to BP in youth, at least at the population level.(79) In another review of studies on secular trends in BP, McCarron et al. (2002) reported historical declines in BP levels among youth and youth adults aged 5 to 34 years in the last 50 years in developed countries.(81)

Why study continuous distribution of blood pressure?

While the high correlation between BP and cardiovascular risk justifies screening adults for elevated BP and then treating those diagnosed as hypertensive to reduce individual risk, the definition of hypertension is operational and even arbitrary. This is because BP in a population is distributed unimodally on a nearly Gaussian curve, slightly skewed to the right, especially in elderly populations.(82) The prevalence of hypertension therefore depends on the choice of a cut point. Although hypertension is defined for US adults as a sustained SBP ≥ 140 mmHg and DBP ≥ 90 mmHg, expert groups at national and international levels (e.g., WHO and the International Society of Hypertension (ISH); the Joint National Committee for the Prevention, Detection, Evaluation, and Treatment of Elevated BP (JNC)) vary in their opinions of where to draw these cut points. The distinction between hypertension and normotension is far from being universally accepted and has been debated for many years, dating back to the classic debate in the 1950s between Sir Roger Platt who believed that hypertension and normotension were two discrete entities and Sir George Pickering who advocated viewing BP on a continuum.(83)

CVD morbidity and mortality also increase continuously across the entire BP distribution.(8, 84) Based on a meta-analysis of one million adults in 61 prospective studies, Lewington et al. (2002) showed a continuous gradient between BP (both SBP and DBP) and CHD and stroke mortality, without any evidence of a threshold in risk.(84) Therefore, while much of BP research in both adults and youth has focused on hypertension, the rationale for this focus and the rigid separation between hypertension and normotension stems from clinical medicine rather than any meaningful cardiovascular endpoints. The size of the left ventricular mass has been shown to increase continuously with BP percentiles in normotensive children.(24-26) Although the risk of elevated BP is 3 times higher among obese children than non-obese children, there is a strong positive association between BP and weight gain across the entire BMI distribution, without an obvious threshold in risk.(70) The need for research that conceptualizes BP on a continuum in youth, without forming subgroups using arbitrary cutoffs has been recently advocated.(85)

While elevated BP in high risk individuals can be effectively managed with anti-hypertensive medication, less is known about the prevention of elevated BP across the entire BP distribution, before the clinical manifestations of elevated BP are evident. While primary prevention aims to reduce already established risk factors, primordial prevention aims to prevent the development of risk in the first place. Yet primary and primordial prevention of elevated BP is important because the large majority of people have suboptimal BP levels that are within the normal range.(6) Since a large number of individuals exposed to low or moderate risk (e.g., SBP < 120 mmHg) generate a greater number of CVD deaths than the small number of individuals exposed to high risk (e.g., SBP > 120 mmHg), the population attributable risk (PAR) for CVD attributable to BP would be greater among normotensive than among hypertensive individuals.(86) With regard to BP, primordial prevention requires effective interventions to prevent increases in BP to undesirable levels. It can involve both high risk and population risk approaches by identifying individuals at the highest risk of progression from desirable to undesirable levels, such as those who are overweight or obese. Since both BP and obesity track from childhood into adulthood, primordial prevention of elevated BP and CVD risk must begin in childhood.(87)

Blood pressure tracking

BP, and SBP in particular, tracks from childhood to adulthood.(88) Tracking refers to whether BP level early in life is predictive of BP later in life by comparing the ranking of individuals at one point in time with the ranking at another point in time. Tracking reflects the degree to which BP values maintain their relative position (e.g., quintile, percentile) in the distribution over time.(89, 90) Tracking is a useful concept for studies involving youth since their absolute BP values change as they grow older.(90)

Tracking was first demonstrated by classic reports from the Framingham(91) and Muscatine studies.(92) Using the Framingham Heart Study data on 2767 adult participants, who had biannual examinations for up to 34 years, Sagie et al. (1993) demonstrated that those with borderline systolic hypertension (SBP $\geq$ 140 and < 160 mmHg) at baseline were at substantially increased risk of hypertension (SBP

≥160 mmHg) (OR=3.84) and of cardiovascular disease (OR=1.39) after 20 years of follow-up.(91)

In the Muscatine Study, biannual assessment of 2445 youth between ages 7 and 18 years, who were examined again at ages 20 to 30 years**,** demonstrated that risk of hypertension in young adults was predicted by BP levels in childhood.(92) The tracking (correlation) coefficients from birth to adolescence vary from r=0.3 to 0.7 for SBP and r=0.1 to 0.6 for DBP.(78) The 6-year correlation coefficients for SBP and DBP in 820 school children in another report from the Muscatine Study were r=0.30 and 0.18, respectively.(93)

The degree of BP tracking during childhood and adolescence is relatively high such that children generally remain within the same BP quartile from early childhood (i.e., age 2 years) through adolescence (i.e., age 17 years).(94) In the Bogalusa Heart Study, 1505 children aged 5 to 14 years were examined at baseline and 15 years later at ages 20 to 31 years.(88) Childhood BP correlated with BP in adulthood (r=0.36 to 0.50 for SBP and r=0.20 to 0.42 for DBP). Further, 40 percent of children, whose BP levels were in the highest quintile, remained in the same quintile 15 years later. Children with SBP in the top quintile at baseline were more than 3 times more likely to develop hypertension in adulthood (OR=3.6) than children in every other quintile. Finally, baseline BP level was the best predictor of BP level at follow-up in the regression analysis, followed by change in BMI.(88)

Recent evidence from Australia,(95) Finland,(96, 97) and Lithuania(98) corroborate that elevated BP levels in childhood or adolescence are predictive of developing hypertension in adulthood. One hundred and thirty-eight children born in 1981-82 in a rural community in eastern Finland were examined at age 6 months, 7 and 15 years. Children in the highest tertile of SBP at 6 months were more likely to remain in the highest tertile at age 7 (RR=4.3) and 15 years (RR=1.9). BMI and change in BMI between age 7 and 15 years were significant predictors of SBP at age 15 years.(96)

A recent meta-analysis of 617 data points for SBP and 547 data points for DBP from 50 cohort studies published between 1970 and 2006, found that BP tracking from childhood into adulthood was strong. The correlation coefficients were, on average, r=0.38 for SBP and 0.28 for DBP.(29) Tracking was stronger for SBP in older than in younger children, and over shorter periods of follow-up. The strength of BP tracking increased with baseline age by 0.012 mmHg for SBP and 0.009 mmHg for DBP and decreased with longer follow-up by 0.008 mmHg for SBP and 0.005 mmHg for DBP.(29)

The strength of BP tracking increases as BMI increases such that BP tracking is strongest in overweight and obese youth. This suggests that excess weight increases the likelihood that elevated BP will persist from childhood into early adulthood. The relative increase in body weight, expressed as a percentile rank, was a significant predictor of the rank order of BP among 4313 children aged 5 to 14 years followed biannually for up to three to six times in the Muscatine

Study.(99) In a Western Australian cohort, BP and BMI were measured every three years in 1,036 children between ages 9 and 18 years and again at age 25 years. The prevalence of overweight and obesity increased in boys and girls, from 10 and 8 percent at age 9 years, to 17 and 14 percent at age 18 years, and then to 42 and 32 percent at age 25 years; SBP at age 25 years was significantly higher in overweight or obese youth.(100)

In sum, the studies reviewed in this section demonstrate that an important determinant of future BP level is initial BP. The presence of elevated BP in youth is therefore of concern because BP in adolescence is an excellent marker for predicting adult BP and CVD risk later in life. Early intervention to prevent elevated BP is needed. Moreover, studies demonstrating the link between obesity and BP tracking underscore the importance of reducing childhood obesity to prevent elevated BP and CVD risk later in life. However, it is important to note that despite BP tracking being strong, many adults with hypertension do not have elevated BP in childhood,(101) indicating that while lowering BP in childhood is important, later factors also play an important role in increasing the risk for elevated BP in adulthood.

Blood pressure measurement

BP measurement in children is difficult and many inaccuracies occur as a result of differences in measurement techniques and devices.(80, 102) Factors that affect BP measurement in youth include: cuff bladder size (i.e., a cuff with too narrow a bladder will overestimate BP level in children); activities before and during measurement (e.g., food, alcohol, caffeine, nicotine, and exercise within 30 minutes of BP measurement as well as movements during measurement can affect the reading); arm and body positions (i.e., an arm placed too high will underestimates BP level and vice versa); time of day (i.e., BP peaks in late morning and mid-afternoon during the day); season and temperature (i.e., BP is lower in warmer temperatures); observer biases (i.e., digit preference, knowledge of prior readings when taking multiple readings over several minutes).(103)

Accurate measurement of BP in youth requires standardized conditions, accurate instruments, and multiple measurements. The preferred method for measurement of BP includes the use of mercury sphygmomanometer or a calibrated aneroid device, use of a cuff width appropriate to the size of the child's upper arm (i.e., cuff width should be at least 40 percent of the child's mid-arm circumference), and the right arm resting on a solid supporting surface at heart level.(104) While most guidelines recommend taking BP readings in a sitting position, there is no consensus of whether sitting or supine positions are better. SBP was found to be the same in either position in adults.(105)

The two main methods for measuring BP are the direct auscultatory method and the indirect oscillometric method. The auscultatory method measures BP with a mercury or aneroid sphygmomanometer and an inflatable cuff, which is first inflated to a level sufficient to complete compress the brachial artery and then gradually released. The first Korotkoff sound (i.e., "whooshing" or pounding) when blood begins to flow into the artery corresponds to SBP. As the cuff pressure is further reduced, the fourth and fifth Korotkoff phases (i.e., when a muffling or no sounds can be heard) correspond to DBP. Measurements are expressed in millimeters of mercury (mmHg). The oscillometric method uses a calibrated automatic device with a numerical readout of BP. The method is based on indirect BP measurement that is made in relation to the auscultatory phenomena of the Korotkoff sounds, which correspond to SBP and DBP. The cuff is first inflated above systolic pressure and oscillations of pressure in the cuff are recorded during gradual deflation. The point of maximal oscillation corresponds to the mean intra-arterial pressure. The values of SBP and DBP are computed as functions of the mean arterial pressure using an algorithm, which is usually proprietary information of the instrument manufacturers. Although aneroid or automatic devices do not use mercury, measurements are reported in units of millimeters of mercury (mmHg).

The auscultatory method was commonly used to measure BP in youth in past epidemiologic studies. However, they are prone to error, including observer bias due to digit preference (e.g., physicians tend to record higher values than nurses and technicians) and knowledge of prior readings; sensitivity to external noise; observer influence on the child (a phenomenon known as the "white coat" hypertension which refers to an artificial rise in BP in the hospital or clinic setting and/or in the presence of a physician or a nurse(106)); use of an inappropriate cuff size; and different arm position (BP increases progressively by about 5-6 mmHg as the arm moves from the horizontal to the vertical position). For example, in the

Bogalusa Heart Study, inter-observer variability was found to be the largest preventable contributor to BP variation in youth.(107)

Because of these issues, the auscultatory method is often difficult to use in children and adolescents,(102) and is being increasingly replaced by automated oscillometric aneroid methods in epidemiologic studies. Automated oscillometric devices have several key advantages. They are convenient to use, they minimize (if not eliminate) observer bias due to digit preference and knowledge of prior readings; they are not sensitive to external noise; the placement of the cuff is less critical. Finally, aneroid devices are gradually replacing mercury manometers in hospitals and clinics because of environmental concerns about the toxicity of mercury. When validated, automated BP devices were used to assess BP in a population-based sample of 2551 adults in Ontario, Canada, they provided a more accurate estimate of BP status than those obtained with a manual sphygmomanometer.(108) Automated oscillometric devices can still lead to bias and must be calibrated regularly against a mercury manometer because they can overestimate BP in youth.(103, 109)

The most widely used automated oscillometric device is a Dinamap (Critikon, General Electric, USA). The digital readout of the Dinamap face plate displays systolic and diastolic pressures, heart rate, and either temperature or mean arterial pressure.(103) The Dinamap device has several key advantages. It requires relatively little training; it avoids observer bias due to digit preference or knowledge of prior readings; it is relatively easy to use with small children because there is no need for auscultation. The BP readings obtained with a Dinamap device correlate well with intra-arterial readings obtained by direct auscultatory method.(103, 110) In the Bogalusa Heart Study, when two Dinamap models (845XT and 8100) were compared with two mercury sphygmomanometers on 417 school children, the Dinamap devices were found to be easy to use and provided accurate readings for SBP but not DBP. (111) Thus, based on existing evidence from childhood epidemiological studies, automated oscillometric devices, such as a Dinamap, may be preferable to the auscultatory method for obtaining BP in children and adolescents.(102, 103, 110) Although Dinamap devices are very expensive (50 to 100 times the cost of a standard mercury sphygmomanometer) they are being increasingly used in epidemiological studies. Some large studies of children, most notably the Child and Adolescent Trial for Cardiovascular Health (CATCH),(112) used Dinamap devices.

Moreover, although the phenomenon of "white coat hypertension" has been observed with a Dinamap device, it is less of a concern when studying changes in BP over time.(103) A meta-analysis of 50 studies published between 1970 and 2006 suggests that automated oscillometric devices may be better suited to assess BP longitudinally, and more specifically, to assess tracking from childhood to adulthood.(113)

Another BP measurement issue is related to the number of BP readings needed to obtain an accurate BP reading. Many previous epidemiologic studies as well as current normative US reference BP data from NHANES, 1999-2000 were based on only one BP reading taken on a single measurement occasion.(34) Yet, because of high reactivity, the first of several BP readings obtained within a few minutes of each other is typically higher, on average by 3 to 5 mmHg, than subsequent readings, which decline with each successive reading taken on the same measurement occasion. More recent studies have relied on an average of two, three, or the last two out of three readings. For improved reliability of BP measurement, it is recommended that the first BP reading be discarded and the remaining readings obtained on the same measurement occasion be averaged.(114)

Although the BP measurement inaccuracies can be improved with the use of correct cuff size, accurate manometer, trained observers, and taking multiple readings on the same measurement occasions, there are two issues in the measurement of BP that affect the accuracy of measurement: the inherent variability of BP in individuals and the tendency of BP to increase in physician's presence (i.e., "white-coat" hypertension).

Blood pressure variability

BP inherently varies in the same individual from moment to moment during the course of the day. The extent of this variability can be substantial and is influenced by many factors, including respiration, emotion, exercise, meals, tobacco, alcohol, external temperature, bladder distension, and pain. BP is also influenced by age, race, and circadian variation. It is usually at its lowest during sleep (called the nocturnal dip). Changes in BP as a result of daily activities, such as working at a desk or reading vs. attending a meeting or washing floors, can be substantial (>20 mmHg for SBP).(115) BP variability is also greater in children than in adults.(102)

Ambulatory BP monitoring studies have demonstrated high variability of BP in youth over time. For example, when 140 youth aged 6 to 17 years were recruited for a trial of antihypertensive medication because their BP was above the 95th sex-, age-, and height-specific percentile during two weeks of the screening stage, 38 (27 percent) dropped out of the study because their BP normalized.(116) In another study, Rucki et al. (2001) found that 54 percent of hypertensive youth aged 8 to 19 years had normal BP after one year of follow-up, while 23 percent of normotensive children became hypertensive one year later.(117) More recently, Stewart et al. (2008) followed 549 children (mean age 9.4 years) presenting to emergency departments with non-urgent problems. When BP was measured at triage, 144 (26 percent) children had elevated BP (BP >95th percentile for sex, age, and height). However, no cases of elevated BP were observed on follow-up.(118) Not only do these studies demonstrate the high variability of BP levels between measurement occasions, they also suggest that elevated BP may be a transient phenomenon in children and adolescents and that it is difficult to diagnose.

Inherent in BP variability is the phenomenon of "white coat" hypertension (WCH). Anxiety raises BP by as much as 30 mmHg so that WCH is considered to be a physiological reaction that is often referred to as a “fight and flight” phenomenon or as a “defense” or “alarm” reaction. While it is often observed in the emergency departments of hospitals when patients are frightened and/or anxious, it may also occur in other settings. Thus, a normotensive person can become hypertensive during BP measurement, but BP then settles to normal levels outside the medical or study environment. While WCH is not observed in everyone, it occurs equally in normotensive and hypertensive subjects. The extent of this physiological reaction varies from person to person. However, it is usually reduced or disappears altogether when the patient becomes familiarized with the technique and circumstances of BP measurement.(106) It has also been suggested that BP taken outside the office is the best method for identifying the “true” BP level of a patient.(114) Studies of ambulatory BP monitoring (ABPM) demonstrated that this phenomenon is highly prevalent in children.(117-119) However, BP readings tend to decrease with repeated measurements as patients become more relaxed and familiar with the measurement procedure.(78)

Also inherent in BP variability is a phenomenon called masked hypertension. It occurs when patients whose “true” BP levels are elevated, have normal BP readings.(120) While WCH reduces the PPV of elevated BP, masked hypertension reduces its negative predictive value (NPV). Lurbe et al. (2005) found that the prevalence of masked hypertension in the general population of youth was about 7.5 percent.(121)

BP variability can bias measured BP levels in either direction. The most common causes of BP overestimation are inadequate cuff size, “white coat” hypertension effect, or recent ingestion of suppressing substances. The most common causes of BP underestimation are smoking or recent exercise. Digit preference by the observer or spontaneous BP variability can either overestimate or underestimate “true” BP. However, despite the inherent variability in individual BP, BP remains a remarkably strong predictor of cardiovascular risk and no better measurable marker yet exists.(54)

Blood pressure increases with age

In most Western populations, BP increases with age. The most substantial increases in BP occur in adolescence,(53) and may be related to the rapid increases in height, weight and body fat, associated with pubertal growth and physiological maturation.(122) While BP increases during this period represent normal human biology, they can be excessive among modern adolescents living in Western societies as a result of physical inactivity and unhealthy levels of caloric intake as well as other deleterious dietary patterns (e.g., excessive intake of sodium) that lead to increased body weight.(123)

There is substantial variation in BP increases with age across different populations. Using data from 34 cross-sectional surveys, Epstein and Eckoff (1967) modeled SBP increases with age and demonstrated substantial variation/diversity in patterns of BP increases with age in different populations.

They classified the patterns of SBP increases with age in individuals 10 and 60 years old into five categories: slope 0 (no SBP change with age) to slope 4 (a high gradient of change of 0.67 mmHg per year).(124) These patterns of population differences in BP levels and slopes were later confirmed by Rodriguez et al. (1994) using cross-sectional data from a single study INTERSALT which included 52 populations in 32 countries.(125) They found a similar diversity in patterns of SBP increases with age ranging from 0.052 mmHg per year of age in Brazil (Xingu) to 1.326 mmHg per year of age in Portugal. BMI had a positive association with the slope of SBP with age. Moreover, large between-population differences in BP levels were already evident at 20-29 years of age, suggesting that BMI and other factors that might lead to these differences in BP increases with age were present at an earlier age. While BP increases with age are endemic in Western, industrialized countries, they are less common in non-industrialized countries.(126) leading experts to urge the prevention of BP increases with age.(123, 127)

The increases in BP with age are also greater among those with higher initial levels of BP.(126) This phenomenon, known as the "horse racing" effect, was first observed among adults.(128) It refers to a positive association between baseline BP (initial level) and its rate of change (slope) over time.(128, 129) The development of BP over the life course, therefore, depends on BP levels during early life, such that BP slopes follow different patterns (e.g., some are linear, other are quadratic). This phenomenon of "horse racing" relates to BP tracking, discussed above.

Patterns of BP increases with age in children and adolescents have been estimated using pooled BP data at different ages from major studies of BP in youth, including the Bogalusa (Louisiana) Heart Study, the Muscatine (Iowa) Study, and Tecumseh studies.(87, 130) Age- and sex-specific analysis of pooled data from 129 surveys worldwide with more than 200,000 observations for SBP and 100,000 observations for DBP in youth aged 6 to 18 years indicated that in boys SBP increased by 1.4 mmHg per year from age 6 to 12 years, 3.2 mmHg per year from age 12 to 15 years and did not increase substantially from age 15 to 18 years. In girls, SBP increased by 1.4 mmHg per year from age 6 to 9 years, 2.1 mmHg per year from age 9 to 13 years, leveled off at age 16 years and declined by 3.4 mmHg per year from age 17 to 18 years.(126)

However, changes in BP with age in the same individual cannot be assessed with these data. Repeated BP assessments in the same individual from existing cohort studies generally corroborate patterns of BP increases with age during childhood and adolescence observed in pooled cross-sectional studies.(87, 131) Specifically, BP increases in boys and girls between ages 6 and 18 years. BP increases are greater in girls until age 12 years when the slopes level off and decline in late teens, while BP continues to increase at a steeper rate for boys until age 18 years. SBP increases from approximately 100 mmHg at age 6 years in both boys and girls until it reaches about 122 and 111 mmHg at age 18 years in boys and girls, respectively.(87, 130, 131)

In sum, these studies indicate that while BP increases with age during childhood and adolescence represent normal human biology, there is substantial variation in the rates of BP increases with age between individuals. Excess weight gain may accelerate the course of BP increases with age, suggesting that in order to prevent elevated BP in adulthood, research studies need to consider the role of obesity in BP increases with age during childhood and adolescence.

Sex differences in blood pressure levels

Before menopause women have lower BP levels than men of the same age.(101, 132) The incidence of hypertension is also higher in men than in women.(133) Although sex differences in BP levels may be associated with higher CVD morbidity and mortality among men,(3) it is not well understood when or how the sex differences in BP appear during the lifecourse.(134)

In Canada and the US, differences in mean SBP levels between men and women aged 35 to 74 years are substantial (127 vs. 77 mmHg), and this difference already exists at ages 35 to 39 years (115 vs. 75 mmHg).(133) Between ages 8 and 18 years, SBP increases in boys by 16 mmHg and 12 mmHg in girls.(131) Indeed, sex differences in SBP increase with age(131, 135) and in the prevalence of elevated SBP(32, 136) are already evident before adolescence, indicating the establishment of differential risk early in life.

In Québec youth, the prevalence of borderline or elevated SBP (i.e., above the 90th percentile for sex, age, and height) at ages 9, 13, and 16 years was 12, 22 and 30 percent in boys and 14, 19 and 17 percent in girls. Thus, the prevalence of elevated BP in boys was almost double that observed in girls by age 16 years.(32) Sex differences in mean SBP levels showed similar trends – the difference in mean SBP between 13 year old boys and girls was 2 mmHg but this difference increased to 10 mmHg by age 16 years.(32) The likelihood of elevated SBP (i.e., above the 90th percentile for sex, age, and height) in boys compared with girls increased from OR=1.29 at age 12 years to 1.98 at age 15 years, and to 2.74 by age 17 years in a convenience sample of Québec youth.(136)

It remains unclear whether sex differences in BP increases with age during adolescence may be due to differences between boys and girls in gains in body size, adiposity, hormones, or some other factors.(134) Although the relationship between BP increases with age and contemporaneous changes in height, weight and body fat on the burden of hypertension has important clinical and public health implications,(6) particularly in the context of the current childhood obesity epidemic,(36, 37) longitudinal cohort studies in this domain have been limited to exploring BP increases with age without considering the effect of changes in height, weight or other adiposity indicators.

Methodological challenges in studying blood pressure increases with age in youth

High BP variability in the same individual implies that the measured value may not necessarily reflect the individual's long-term mean BP level. This makes it easy to misclassify the individual's "true" BP level, leading to large measurement error. The variance of BP in a population can be divided into the between-person component and the within-person component. While the between-person component of BP variance is a property of interest in epidemiological studies, the within-person component is similar to measurement error in that it can bias estimates of effects and correlations, and needs to be taken into account. Since BP variability is greater in children than in adults,(102) the within-person variance also represents a higher proportion of the total variance in children compared with adults. For this reason, it is important to take into account or correct for within-person variability in studies of BP in youth. This is particularly important in children, whose BP variability is high, and therefore any one reading is less likely to represent the "true" BP level.(102) At the data collection stage, BP reliability can be improved by increasing the number of readings on the same measurement occasion.(103)

High BP variability also poses methodological challenges to studying BP change over time in youth at the analysis stage. Most past studies assessed BP change in youth using tracking, which reflects the degree to which BP values maintain their relative position (e.g., quintile, percentile) in the distribution over time. There are two main methods for assessing tracking: *correlation*, which measures the extent to which paired individual levels of initial and follow-up/subsequent BP levels co-vary, and regression, which estimates the average change in follow-up BP levels from initial levels. Correlation coefficients using relative values in youth, such as percentile ranks assesses whether this ranking persists between measurements months or years apart and how accurate individual prediction of subsequent BP is base on their initial level. Regression allows examination of the average strength of an association and can be translated into relative risks or odds ratios. Most often, tracking has been assessed using some measure of correlation, such as Pearson or Spearman's correlation coefficient, kappa, or the intra-class correlation (ICC). More recently, regression methods have been used to study changes in BP. Since it assesses correlation in a group of individuals, tracking reflects the association between initial and subsequent BP levels at the population level. However, whether assessed by correlation or regression, these methods do not take large intra-individual variability in BP on different measurement occasions into account.(89, 90, 137) The observed tracking coefficients are therefore attenuated since they reflect the effect of intra-individual variability in BP, some of which may not be "true" variation (i.e., random error).

Tracking also assumes that individual rates of BP increase are constant over time (i.e., parallel slopes).(138) The strength of tracking (correlation) coefficients in studies of BP in youth can be improved by taking into account or correcting for within-individual variability.(139) Analyzing BP change over time in the same individual using individual growth modeling breaks down the random error term into within- and between-individual variance components; it can reduce the impact of intra-individual variability and improve the precision of tracking estimates. In a cohort of 333 school children aged 8 to 15 years at baseline, BP was assessed annually for four consecutive years. When tracking correlations were corrected for intra-individual variability using individual growth modeling, age- and sex-adjusted tracking correlations over three years increased from 0.43 to 0.73 for SBP, and from 0.20 to 0.70 for DBP.(139) Shea et al. (1998) applied individual modeling to six repeated measurements of SBP in children and showed substantial variability in the average rate of change (slope) over time, 33 percent of which was ascribed to random error.(138)

Advanced longitudinal analysis methods, such as generalized estimating equations (GEE) or individual growth models that take intra-individual variation in BP into account, are more suitable for the analysis of repeated measurements of BP.(90, 138) In addition to GEE, individual growth modeling is particularly appropriate for the study of BP change during childhood and adolescence. Both GEE and individual growth modeling account for the non-independence of repeated observations inherent in longitudinal data with repeated measures. However, individual growth modeling has the advantage over GEE as it also reflects the variation in individual-specific BP slopes by providing statistical terms for the mean slope (fixed effect) and individual-specific deviation from the mean slope (random effect).(140) Yet few studies have applied individual growth modeling to the study of BP change over time. In sum, few studies have examined individual patterns of BP change and its determinants in adolescence employing analytical techniques that adjust for intra-individual variability in BP.

The first objective of this thesis is to assess the sex-specific impact of changes in height and indicators of adiposity such as BMI, waist circumference, and skinfold thickness, on SBP increases with age during adolescence. To address this objective, I will use individual growth modeling to adjust for intra-individual variability in SBP.

Prevention of elevated blood pressure in youth

Prevention in clinical populations of youth

Maintaining a healthy body weight and regular physical activity are strongly recommended for both the prevention and management of elevated BP in both adults and youth.(34, 141) Maintaining a healthy body weight requires a balance between energy intake and energy expenditure.(142) Our modern societies, however, promote physical inactivity and sedentary behaviour, leading to positive energy balance and weight gain. The prevalence of overweight and obesity in youth increased almost threefold in the last two decades.(35, 38) In Canada, 26 percent of youth aged 2 to 17 years were overweight or obese in 2004, compared with 15 percent in 1978/1979.(38) The prevalence of overweight and obesity increased between 1993 and 1997 among elementary schoolchildren aged 10 to 12 years in inner-city, multiethnic, low-income neighborhoods in Montréal, Canada.

The prevalence of overweight was 35.9 percent in 1993 and increased by 1.3 percent per year, while the prevalence of obesity was 15.9 percent in 1993 and increased by 1.0 percent per year.(143) Alarming increases in the prevalence of obesity over the last two decades have propelled the issue of obesity prevention to the forefront of the public health policy agenda.(37) Obesity prevention in youth is considered to be a major public health priority today.(142, 144) Obesity prevention in youth is also important because obesity tracks from childhood to adulthood,(41, 42, 145, 146) The risk of obese children becoming obese adults is 2 to 6.5 times higher than for non-obese children.(147)

Healthy levels of physical activity in youth require regular participation (4-5 times per week) in activities that generate energy expenditure above the normal resting levels, including both structured and unstructured activities. Guidelines for the prevention and management of elevated BP in youth recommend the accumulation of 30 minutes of physical activity daily and an additional 20 minutes of vigorous physical activity three times a week.(34) However, prevalence of physical inactivity in Canadian and US youth has increased in recent decades because youth are more likely to rely on cars than to walk or use bicycles; and they are more likely to engage in sedentary recreation such as television viewing, playing video games and computers. According to the Youth Risk Behaviour Survey (YRBS) conducted biannually from 1993 to 2003, the prevalence of inactivity increased substantially from grades 9 to 12 and the odds of being inactive increased by 40 percent between 1993 and 2003 among youth.(148)

Canada's Physical Activity Guidelines for children and adolescents recommend accumulating at least 90 minutes of moderate-to-vigorous physical activity over the course of the day, in bouts of at least 5 minutes in duration.(149) However, less than 10 percent of Canadian youth aged 5-19 years attain these recommendations,(149, 150) even fewer continue to sustain these levels into adulthood.(151)

Moreover, physical activity levels decline dramatically with age, with the decline being particularly pronounced during the transition from childhood to adolescence and during adolescence (between ages 13 and 18 years).(55-57) Leisure-time physical activity also declined substantially during adolescence in 1,213 black and 1,166 white girls followed prospectively for 10 years from ages 9-10 to 18-19 years in the National Heart, Lung, and Blood Institute (NHLBI) Growth and Health Study.(57) The physical activity scores were 27.3 and 30.8 metabolic equivalents (MET)-times per week at age 9-10 years in black and white girls; this declined to 0 and 11.0 by age 18-19 years, indicating a 100 percent and 64 percent decline in black and white girls, respectively. By age 16 or 17 years, 56 percent of white and 31 percent of black girls reported no habitual leisure-time activity. Moreover, a greater decline in physical activity was associated with higher BMI among girls of both races.

Increased exercise and weight loss in adults

Both clinical and observational studies identify excess weight as the strongest predictor of elevated BP in adults.(152, 153) Clinical studies assessing the effect of weight loss on BP in adults suggest that excess weight is likely causally associated with elevated BP.(154) Changes in BP following weight gain or weight loss occur rapidly. While weight loss of as little as 4-5 kg in hypertensive adults can lead to normalization of their BP levels within as little as 2-3 weeks, weight gain in normotensive adults is associated with increases in BP over as short a period as one or two months.(152) Indeed, the cumulative effects of weight loss and increased exercise in adults lead to comparable reductions in BP levels achieved by antihypertensive drug therapy, and even modest reductions in body weight can eliminate the need for antihypertensive drug therapy.(152, 155)

A meta-analysis of 25 randomized controlled trials of 4,874 overweight and obese adults, published between 1966 and 2002, showed that body weight was reduced, on average, by 5.1 kg through energy restriction, increased physical activity, or both, while SBP declined by 4.44 mmHg and DBP by 3.57 mmHg. Thus, for every kilogram of weight loss, SBP and DBP declined, on average, by 1.05 and 0.92 mmHg, respectively.(156) Another meta-analysis of 54 randomized controlled trials with 2,419 participants, published before September 2001, in which the intervention and control groups differed only in exercise, showed that exercise was associated with a significant reduction in SBP of 3.84 mmHg and DBP of 2.58 mmHg.(157) Although a reduction in BP was observed in both hypertensive and normotensive participants, and in overweight and normal weight participants,(157) the health benefits of weight loss were greater for those with higher BP levels. A meta-analysis of 72 randomized controlled trials of increased exercise found SBP and DBP both declined by 3 mmHg on average in normotensive, by 6 and 7 mmHg, respectively, in borderline hypertensive, and by 10 and 8 mmHg in hypertensive participants.(158)

While many studies have assessed the short-term effects of weight loss on BP, few extended the follow-up beyond two years. Yet the hemodynamic benefits of weight loss or maintenance may be smaller when changes in body weight occur over longer periods than those observed in the short-term.(159, 160) A systematic review of studies with a follow-up greater than two years, published from 1966 to 2001, found that for every kilogram of weight loss, SBP and DBP decreased by 0.6 mmHg and 0.46 mmHg, respectively, in obese adults (BMI$\geq$ 28 kg/m^2).(160) However, the magnitude of the effects from studies with longer follow-up was about half those obtained in short-term studies. Therefore, studies in adults indicate that extrapolation of short-term changes in BP associated with weight loss to the longer term may be misleading.

The protective effect of physical activity on BP is also well established in adults.(157, 161) A physically inactive lifestyle in adulthood is associated with a two-fold increase in the risk of elevated BP and CVD.(162) Increases in physical activity in intervention studies in adults were associated with reductions in BP in as little as 9 weeks.(163) Moreover, increases in physical activity reduced obesity and prevented further weight gain in adult men, even without caloric restriction.(164)

Increased exercise and weight loss in youth

Intervention studies in youth are divided into treatment of overweight or obesity in clinical populations of youth and prevention of weight gain among otherwise healthy, normal weight youth. I review intervention studies in both clinical and non-clinical populations of youth below.

Clinical studies show that weight loss in overweight and obese, or hypertensive youth is also associated with a decrease in BP.(165, 166) Among 203 obese (mean BMI=26.9) children aged 6 to 14 years, who participated in a one-year intervention program of physical exercise, nutrition education, and behaviour therapy, the SBP and DBP in 126 children who were successful in reducing their BMI declined by 8 and 12 percent, respectively.(165) Following a 6-week program of intensive physical exercise and dietary changes in obese adolescent girls, Wabitsch et al. (1994) found 8.5 kg reductions in body weight and significant reductions SBP and DBP.(166) An exercise intervention study in adolescent girls at risk for hypertension found a reduction of 6.0 mmHg in SBP and 0.3 BMI units following an 18-week exercise intervention.(167) Table 2.1 provides a summary of intervention studies of increased physical activity and weight loss in clinical populations of youth. These studies demonstrate a consistent and clinically important relationship between excess weight and BP, and between weight loss and reduction in BP.

Reviews and meta-analyses of intervention studies in clinical populations of youth generally support a causal link between physical activity and BP, independent of body weight loss, and provide evidence that even short-term (e.g., 2-12 weeks) increases in physical activity levels result in reductions in SBP of 1-6 mmHg.(165, 168-171) However, a review of 24 studies of the effect of exercise training on BP among adolescents found that changes in BP were both in the upward and downward direction.(172) Moreover, a meta-analysis of 12 exercise intervention studies of at least 8 weeks in youth failed to find a significant reduction in BP following exercise training; BP decreases were statistically significant in only one-third of these studies.(173)

Most intervention studies focused on the management of high BP through exercise and/or diet among obese or hypertensive children and adolescents. While beneficial effects were apparent in obese or hypertensive youth, results among the normal weight and normotensive children are less clear.(152, 172) The effect of physical activity on BP may be more consistent among obese and hypertensive youth because, similar to adults,(158) reductions in BP following exercise are likely to be greater in these groups than in normal weight and normotensive youth, whose BP may be less amenable to change.(172)

While weight loss through increases in physical activity in clinical populations of obese or hypertensive youth is beneficial for BP, less is known about the effect of changes in physical activity and weight status on BP in non-clinical populations of youth. It is important to consider the effect of physical activity across the entire distribution of blood pressure to address the question of primary prevention of elevated blood pressure, rather than its management in high-risk groups.(86)

TABLE 2.1. Intervention studies of increased physical activity for treatment of overweight and elevated blood pressure in clinical populations of youth

Author, year	Sample	Baseline age or grade	N	Follow-up	Intervention Components	Intensity	Frequency	SBP change	BMI change	Comments
Reinehr et al, 2006(165)	BMI>97 percentile	6-14 y.o.	240	1 year	ballgames, jogging, jumping, PE instruction for 1 year	N/A	1 day/week	↓ 4.0 mmHg	↑ 0.1 kg/m^2	BMI increased by 0.1 kg/m^2 in intervention group compared with 2.0 kg/m^2 in control. SBP declined from 120.3 mmHg to 116.0 mmHg 1 year later in intervention, compared with an increase in control group from 119.4 mmHg to 124.7 mmHg
Ribeiro et al, 2005(174)	BMI>95 percentile	10-11 y.o.	21	16 weeks	walking, jogging, recreational exercise	heart rate 10% below ventilatory threshold	60 mins 3 days/week	↓ 6.0 mmHg	↓ 3.0 kg/m^2	Compared with 10 lean controls, BP and BMI reduced

										significantly in obese children following diet and exercise training
Watts et al, 2004(175)	BMI>97 percentile	12-16 y.o.	19	8 weeks	circuit training	65-85% heart rate max	60 mins 3 days/week	N/A	↓ % 0.3 kg/m2	Circuit training improved body composition in obese adolescents
Woo et al, 2004(176)	BMI>21	9-12 y.o.	82	1 year	exercise training	60-70% heart rate max	75 mins 1-2 days/week	N/A	↓ 0.1 kg/m2	Little change in BMI, significant reductions in body fat % after 1 year
Gutin et al, 1999(170)	tricep skinfold>85 percentile	7-11 y.o.	73	8 months	physical training for 4 months	high intensity 75-80%	40 mins 5 days/week	no change	↓ %BF, VAT	Physical training lead to favourable changes in body composition after 8 months
Ewart et al, 1998(167)	BP>67 percentile	grade 9	88	18 weeks	aerobic exercise PE classes	N/A	50 mins 5 days/week	↓ 6.0 mmHg	↑ 0.3 kg/m2	SBP declined by 6.0 mmHg in intervention and 3.7 mmHg in healthy controls; No significant

										difference in BMI change between two groups. Aerobic exercise during PE class had a greater reduction in SBP than standard PE classes
Wabitsch et al, 1994(166)	BMI=31.3	14-16.5 y.o.	116	6 weeks	swimming, ball games, jogging	N/A	60-120 mins 5 days/week	↓ 8.8 mmHg	↓ 3.2 kg/m2	Significant weight loss and reduction in SBP and DBP
Hansen et al, 1991(177)	BP≥95 percentile	6-9 y.o.	137	8 months	extra regular PE class: organized games, gymnastics, and exercises	N/A	50 mins 1 day/week	↓ 4.9 mmHg	↑ 3.2 kg	Weight increased by 3 kg in intervention group, compared with 2.8 kg in healthy controls; SBP declined in both intervention and control

										groups (4.9 vs. 6.5 mmHg)
Becque et al, 1988(171)	BMI and triceps skinfold>75 percentile	12-13 y.o.	36	20 weeks	walking, jogging, aerobic activities	60-80% age-predicted max	50 mins 3 days/week	↓ 1.4SD	↓ 3.0 %fat	Significant reduction in SBP and body fat after 20 weeks of exercise, diet and behaviour change intervention
Rocchini et al, 1988(74)	BMI>75 percentile	10-17 y.o.	25	20 weeks	aerobic walk, jog activities	70-75% max heart rate	40 mins 3 day/week	↓ 16 mmHg	↓ 2.4 kg	Reduction in SBP greatest after exercise and caloric restriction combination
Hagberg et al, 1983(178)	BP>95 percentile	15-17 y.o.	25	5-7 months	walking, jogging	70-80% of VO2 max	30-40 mins 5 days/week	↓ 8.0mmHg	No change	No significant changes in weight or skinfold thickness; SBP and DBP declined significantly following exercise. Body weight increased

				significantly and BP returned to baseline levels 9 months after intervention.

Abbreviations: BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; VAT, visceral adipose tissue; y.o., years old; BMI, body mass index (kg/m^2); PE, physical education.

Prevention in non-clinical populations of youth

While even modest increases in exercise may result in weight loss and reductions in BP in clinical populations of youth, prevention interventions in non-clinical populations of youth have been less encouraging. A systematic review of 24 randomized controlled studies with a follow-up of at least 12 months, with 25,896 children from both clinical and general populations, published before 2004, found that only 15 studies reported positive effects.(48) A Cochrane review of 22 intervention studies in non-clinical populations of youth, with a minimum duration of 12 weeks, published from 1990 to 2005, found that nearly all studies reported modest improvements in diet or physical activity. However, only a few showed small improvements in BMI and the improvements were small. The authors concluded that prevention interventions can be effective in promoting a healthy diet and increased physical activity in youth, but they were not effective in preventing excess weight gain in children and adolescents.(50) Another review of 11 intervention trials published between 2000 and 2004, to prevent excess weight gain in youth concluded that such trials are few in number and that there is little evidence that increasing physical activity is effective in preventing obesity and weight gain.(179) Collectively, these studies highlight a lack of evidence of the protective role of increased physical activity in the prevention of high BP development in youth.(179, 180)

Moreover, a systematic review of randomized controlled trials that specifically targeted increases in physical activity for at least 1 year in duration in children or adolescents, published before May 2002, found that the evidence on childhood obesity prevention was limited and not encouraging.(181) The authors concluded that while improvements in physical activity were effective in the treatment of obese children and adolescents, the effectiveness of obesity prevention interventions in non-clinical populations of youth was unclear. Another review of studies that focused on the role of physical activity in the prevention of CVD risk factors in youth found that although the association between physical activity and CVD risk factors was weak overall, physical activity explained a small amount of the variance in CVD risk factors but only in high risk populations of overweight and obese, or hypertensive youth.(182) Finally, the most recent meta-analysis of school-based physical activity interventions, based on 18 randomized controlled trials, involving 18,141 children, published before September 2008, found that they did not improve BMI.(183)

Similarly, studies that targeted improving BP levels and other CVD risk factors in general populations of youth had limited success. For example, the Child and Adolescent Trial for Cardiovascular Health (CATCH) was a large school-based randomized controlled field trial. It included 5,100 adolescents in grades 6-8 in 56 intervention and 40 control schools in four US states (California, Louisiana, Minnesota, and Texas) followed up for 3 years. It was the first trial of CVD prevention in youth that included intervention components at the individual, school, and family levels.(112, 184, 185) Intervention components included changes in the fat content of lunches offered at schools and in the amount of moderate-to-vigorous physical activity (MVPA) in physical education (PE) classes at the school level. After three years, students in intervention schools reported engaging in higher levels of daily vigorous activity than students in control schools (30.2 vs 22.1 minutes).(184, 185) However, there were no differences in total levels of activity between students in intervention and control schools.(184) Moreover, improvements in daily levels of vigorous physical activity in the intervention group did not result in significant reductions in adolescents' BP or BMI. This trial provides the best evidence to date that changes in BP and BMI in general populations of youth following prevention interventions are modest at best.

Results of this and other major school-based CVD prevention intervention studies targeting non-clinical populations of youth are summarized in Table 2.2. Taken together, the evidence from well-controlled and well-conducted studies, as well as from systematic reviews and meta-analyses suggest that while prevention interventions in non-clinical populations of youth produced significant improvements in health knowledge and modest improvements in physical activity levels, they did not achieve significant changes in physiological indicators, including reductions in weight and body fat, and BP.(186) Modification of CVD risk factors in general populations of school-aged youth is difficult at best, and current population-based policies that mandate increased physical activity in schools are unlikely to have a significant effect on preventing excess weight gain or elevated BP in youth.(186) Indeed, in the absence of supportive evidence, current recommendations for increased physical activity to prevent higher BP in youth are based primarily on extrapolation from studies in adults.

TABLE 2.2. School-based intervention studies of increased physical activity for prevention of weight gain and higher blood pressure in youth

Author, year	Study	Population	Baseline age or grade	N	Research Design	Follow-up	Theoretical Framework	Intervention Components	Comments
Walter et al, 1988(187)	Know Your Body (KYB 1)	Bronx, NY; Westchester, NY (USA)	grade 4 (mean age 9.1 y.o.); 37 schools	3388	Random assignment of schools within districts	Baseline, 1, 2, 3, and 5 years	HBM, SCT	Health education programs by teachers on nutrition, physical activity and smoking prevention.	One of the first theory-driven school-based CVD prevention programs. No significant changes in CVD risk factors after 5 years.
Bush et al, 1989(188)	Know Your Body (KYB 2)	Washington, DC (USA)	grade 4-6 (mean age 10.5 y.o.); 9 schools	1041	Block randomzed (by SES)	Baseline and 2 years	SCT	Health education programs by teachers on nutrition, physical activity and smoking prevention. Heart health information for parents.	Extension of KYB1 to black children. Significant reductions in SBP and DBP after 2 years.

Luepker et al, 1996; Nader et al, 1999(184, 185)	Child and Adolescent Trial for Cardiovascular Health (CATCH)	California, Louisiana, Minnesota, and Texas (USA)	grade 3-5 (mean age 8 y.o.); 96 schools (56 intervention)	5105	Randomized contolled field trial	Baseline and 3 years	SCT	Multi-level interventions. Schools: food services and PE classes; family and individual: nutrition and PA education.	The first multicentre school-based RCT. Significant improvements in MVPA in PE classes and PA outside of school. No significant changes in CVD risk factors after 3 years.
Harrell et al, 1996(189)	Cardiovascular Health in Children and Youth Study I (CHIC I)	USA	grade 3-4 (mean age 8-11 y.o.); 12 schools (6 intervention)	1274	Randomized controlled field trial, stratified by region and urban/rural setting	Baseline and 2 years	SCT	Multi-level interventions. Health education programs by teachers on nutrition, physical activity and smoking preventon. Aerobic activity intervention (24 sessions	Improved knowledge of CVD risk factors and significant improvements in self-reported PA in intervention group. Significant reductions in body fat but not in BP.

								over 8 weeks).	
McMurray et al, 2002(190)	Cardiovascular Health in Children and Youth Study II (CHIC II)	USA	11-14 y.o.; 5 rural schools	1140	Randomized controlled field trial; 2x2 factorial design (3 treatment, 1 control)	Baseline and 8 weeks	SCT	Exercise only, education only, excersice and education intervention groups. Exercise (3 days/week over 8 weeks). Health education by teachers.	Significant improvements in BP in all intervention groups, independent of weight loss. Improvements in skinfold thickness in exercise group. No significant differences in BMI.
Simons-Morton et al, 1991(191)	Go for Health	Texas (USA)	grade 3-4; 4 schools	1156	Random assignment of schools	Baseline and 2 years	SCT	Health education by teachers; enhanced PE classes and food service	Substantial increases in PA in PE classes after 2 years.

Berenson et al, 1991(192)	Heart Smart Program	USA	grade 4-5; 4 schools	556	Random assignment of schools	Baseline and 1 year	SCT	Individual: health education by teachers; schools: changes to PE classes and food service	Improved knowledge of CVD risk factors. Significant improvements in sodium and sugar content in school lunches. No significant changes in BMI, SBP, DBP.
Gortmaker et al, 1999(193)	Planet Health	USA	grade 6-8; 10 schools (5 intervention)	1295	Random assignment of schools matched by ethnic composition, town	Baseline and 2 years	SCT, Behavioural choice theory	Health education program by teachers (16 sessions/year over 2 years) on TV, fat intake, physical activity and nutrition.	Decrease in obesity prevalence as a result of reduced TV watching.
Killen e tal, 1988(194)	Stanford Adolescent Heart Health Program	Stanford, CA (USA)	grade 10 (14-16 y.o.); 4 schools	1130	Randomized block assignment by ethnic distribution, school size	Baseline and 4 months (2 months after intervention)	SCT, Social inoculation theory	Health education program (20 sessions, 7 week interval, 50 min/session) on physical	Improved knowledge of CVD risk factors and significant improvements in self-

								activity, nutrition, and smoking prevention.	reported PA in intervention group. Significant reductions in obesity (in girls only) but not in BP.
Bayne-Smith et al, 2004(195)	Physical Activity and Teenage Health	New York City, NY (USA)	grade 9-12; 3 schools	442	Random assignment of classes in schools	Baseline and 3 months	N/A	Health education by teachers on CVD risk factors, exercise and nutrition, stress, smoking cessation. Vigorous PE curriculum.	Improved knowledge of heart health, eating habits. Significant reductions in body fat and BP.
Dwyer et al, 1983(196)		Adelaide, South Australia	grade 5 (mean age 10 y.o.); 7 schools	216	Random assignment of classes in schools	Baseline, 14 weeks and 2 years	N/A	Intensive PE program (75 mins./day) for 14 weeks	Significant improvements in body fat after 14 weeks and 2 years. No significant reductions in BP.

Reilly et al, 2006(197)	Glasgow, Scotland	pre-school (mean age 4.2 y.o.); 36 nurseries	545	Random assignment of nurseries	Baseline, 6 and 12 months	N/A	Enhanced physical activity (30 mins./day 3 times/week for 24 weeks), health education on increasing physical activity through play and reducing sedentary behaviour	No significant effect of intervention on PA, sedentary behaviour, or BMI in young children.

Adapted and updated from Hayman et al (2004).(186)

Abbreviations: HBM, Health Belief Model; SCT, Social Cognitive Theory; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; y.o., years old; BMI, body mass index (kg/m^2); PA, physical activity; MVPA, moderate-to-vigorous physical activity; PE, physical education.

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In contrast, several studies suggest that school-based obesity prevention interventions led to reductions in body weight and/or BP. In a school-based intervention trial of 442 adolescent girls, SBP and percent body fat declined substantially following a 12-week program of vigorous exercise training, combined with health behaviour education.(195) In another 8-week school-based trial that increased the exercise component of the physical activity program for 11-14 year old youth in schools, SBP declined by 2.8 mmHg in the exercise intervention group and increased by 1.8 mmHg in the control group. BMI did not change significantly and the sum of skinfolds increased less in the exercise group than among controls.(190) More recently, Foster et al. (2008) reported a 50 percent reduction in the prevalence of overweight following a 2-year school-based obesity prevention intervention among 1,349 students in grades 4 through 6 from 10 schools in the US. The incidence of overweight during 2 years was 7.5 percent in the intervention group and 14.9 percent in the control group.(198)

The effectiveness of obesity prevention interventions is often assessed by comparing the prevalence of overweight and/or obesity pre- and post-test. However, changes in mean BMI may be a more appropriate metric when assessing the effectiveness of such interventions.(199) Even though Foster et al. (2008) reported a decline in the incidence and prevalence of overweight, the mean BMI and BMI Z-score were similar in the intervention and control groups over the two-year period. Thus, the average weight gain, as assessed by changes in the overall BMI distribution curve, is a better metric when assessing the impact of obesity prevention interventions. This is because changes in BMI in children who cross the 85^{th} and 95^{th} cutoff percentiles for overweight and obesity do not represent weight changes in children across the entire BMI distribution, nor do they reflect the magnitude of weight gain during the intervention.(199) Indeed, when Reilly et al. (2006) assessed the impact of a cluster randomized controlled trial of physical activity to prevent obesity in 545 pre-school children using changes in BMI Z-score, they failed to find significant reductions in BMI in children after 6 and 12 months of follow-up.(197)

Lastly, observational studies have demonstrated a link between excess weight and BP in youth as early as 1970s, based on data from the Bogalusa (Louisiana) Heart Study.(200) Most observational studies, however, were cross-sectional and generally found a strong positive association between BMI level and BP in youth across the entire BMI distribution, without an obvious threshold in risk.(70) Using data from a representative sample of 3,589 youth aged 9, 13, and 16 years in Québec, Canada, Paradis et al. (2004) demonstrated that in all age-gender groups, the higher the quintiles of BMI, the higher were the mean SBP and DBP.(32)

Several longitudinal studies that examined the association between changes in weight and changes in BP in non-clinical populations of youth also indicated that both excess weight and change in weight were independent and strong predictors of SBP increases in youth, and the greatest increases were among those with the largest weight gain. The Muscatine Study assessed BMI and BP in 2,925 children once between ages 6 and 15 years and again between 15 and 18 years. Children whose weight decreased relative to their peers had corresponding declines in SBP and DBP, while children who gained weight had an increase in their SBP and DBP levels. These effects were independent of initial BP.(201) In the Minneapolis Children's BP Study, 679 children (mean age 7.7 years) were followed until they were 23.6 years of age. Initial weight as well as increases in weight during childhood were significantly related to SBP in young adulthood.(202) Using data on 2,794 children from Brisbane, Australia, Mamun et al. (2005) examined the association between BMI changes between ages 5 and 14 years on BP at age 14 years. Results showed that children who were overweight at both ages or who gained weight (i.e., normal BMI at age 5 but overweight at age 14) had higher BP at age 14 than children who had a normal BMI at both ages.(203) In a US school-based cohort, 2,089 youth aged 5 to 19 years were examined annually between 2004 and 2006. SBP increased 0.77 mmHg for every kilogram of weight gain over a period of the 2 years. However, among children with similar SBP and BMI at baseline, children with the largest increase in BMI over two years had 4.5 times greater increases in BP, compared with children with minimal weight gain during follow-up.(204) These studies collectively support the need for interventions to prevent excess weight gain in children and adolescents.

Cross-sectional studies have shown significant associations between physical activity and obesity in youth.(144, 205) Physical inactivity related strongly to obesity in 5,890 11-16-year-old Canadian adolescents from a nationally representative cross-sectional sample of the 2001/02 World Health Organization

Health Behaviour in School-Aged Children Survey. While there were no clear associations between dietary habits and measures of overweight and obesity, physical activity levels were lower in overweight and obese boys and girls than in normal weight youth.(206) Similarly, the population-based cross-sectional Avon Longitudinal Study of Parents and Children, physical activity measured by accelerometer and obesity by dual x-ray emission absorptiometry (DXA) scanner in 5,500 12 year old children showed a strong negative dose-response association between MVPA and obesity,(207) but only small inverse associations between PA and BP. SBP declined by 0.66 mmHg per 15 minutes a day of MVPA.(208)

The evidence on the longitudinal relation between habitual, not imposed, physical activity and obesity is limited in youth,(209) and the role of physical activity in preventing obesity and elevated BP during adolescence remains unknown. While exercise is a sub-category of physical activity and involves activities that are planned, structured and repetitive, habitual or leisure physical activities are unplanned and unstructured. Longitudinal cohort studies in non-clinical populations of youth that examined the longitudinal relation between changes in habitual, rather than imposed, physical activity and BP are few. Studies vary in their conclusions because of confounding, reverse causality and measurement error.(179) In a prospective cohort study of grade 4 and 5 students in 16 elementary schools located in inner-city, multiethnic, low-income neighborhoods in Montréal, Canada, initial overweight and obesity (OR=3.26), engaging in no sports outside school (OR=2.14), and being least active (OR=2.18) were significant two-year predictors of excess weight in 633 children age 9 to 11 years.(210) In the Project HeartBeat!, a longitudinal study of CVD risk factors and their behavioural determinants in children and adolescents, MVPA was inversely associated with BMI and fat mass in 472 youth aged 10-18 years.(211) For every 100 minute-per-day increase in MVPA, BMI and fat mass declined by 0.20 and 0.14 kg/m^2, respectively.

Declines in habitual physical activity in late childhood and adolescence were significantly related to changes in BMI and skinfold thickness in a cohort of 1152 US black and white girls age 9-10 years at baseline who were assessed annually over 9 to 10 years of follow-up.(212) Each decline in physical activity of 10 metabolic equivalent [MET]-times per week was associated with an increase in BMI of 0.09 and 0.14 kg/m^2 and in skinfold thickness of 0.62 and 0.63 mm in black and white girls, respectively. At age 18 or 19 years, BMI differences between the most and least active girls were 4-6 kg and 6-9 kg in black and white girls, respectively. This study provided the first strong longitudinal evidence from a large and well-designed observational study of youth that declines in physical activity during adolescents relate to obesity. Since gradual declines in habitual physical activity over time lead to increased overweight and obesity through sustained energy imbalance, prevention of the steep declines in physical activity during adolescence is potentially a cost-effective prevention strategy to prevent obesity and higher BP in youth.(213)

Changes in self-reported physical activity over three years (between age 12 and 15 years) related inversely to changes in SBP in a representative sample of 459 adolescents from the Northern Ireland Young Hearts Project.(214) In the Dietary Intervention Study in Childhood (DISC), self-reported physical activity increased over three years (between age 8-10 and 11-13 years) and was also inversely related to SBP in 663 youth with elevated cholesterol at baseline, followed over three years. For every 100 METs (based on self-reported physical activity) SBP decreased by 1.5 mmHg, while for every 10 hours of intense physical activity BMI declined by 0.2 units. However, BP and BMI were used as separate outcomes in this study and potential mediation of the relationship between physical activity and BP by obesity (BMI) was not considered.(215) Overall, existing longitudinal studies generally show that physical activity is at best only weakly associated with changes in BP.(205)

Several observational studies have examined the effect of physical activity in adolescence on BP in adulthood, including the Aerobics Center Longitudinal Study,(216) the Amsterdam Growth and Health Study,(217) the Northern Ireland Young Hearts Project,(218) the Danish Youth and Sports Study,(219, 220) and the Leuven Longitudinal Study on Lifestyle, Fitness and Health.(221) While these studies suggest that a physically active lifestyle in adolescence and young adulthood was negatively associated with body fatness, there was little evidence for a protective effect of physical activity in adolescence on BP in adulthood.(172, 205)

The studies reviewed in this section highlight the importance and the need for prevention strategies that promote increased physical activity and prevent excess weight gain in youth in order to reduce the burden of elevated BP and CVD, although they fail to show strong association between physical activity and BP.

Methodological challenges in studying the association between physical activity, obesity and blood pressure in youth

Existing studies on the relation between physical activity and BP in youth have a number of limitations, including small sample sizes, use of clinical populations, and difficulty assessing physical activity. Since the effect of being physically inactive on BP may not manifest quickly, frequent assessments of physical activity over several years of follow-up may be required to adequately assess the longitudinal relations between physical activity and BP in youth. Yet, few longitudinal studies have examined this association in general populations of youth over long time periods using multiple data points.

Longitudinal associations between physical activity, obesity and BP in youth reported to date may be modest because of random error due to large intra-individual variability in BP. Most longitudinal studies to date had only one or two data points for BP, and in addition, relied on methods that do not take this variability into account, leading to an attenuation of a possible effect. Exercise intervention studies are prone to the same limitation since they involve pre- and post-test study designs with two data points for BP to assess differences in BP before and after the intervention. Several studies have used generalized estimating equations (GEE) to examine the association between physical activity and BP. Using data from the Amsterdam Growth and Health Study, Twisk et al. (2000) modeled physical activity changes using 6 data points in 181 youth over 14 years of follow-up from age 13 to 27 years. They reported that while physical activity tracked from adolescence to adulthood and was related to the sum of skinfolds, it was not related to BP. However, their analysis relied on one BP point in adulthood at age 27 years.(222)

Using data from the Northern Ireland Young Hearts project (n=459), Boreham et al. (1999) examined a three year change in BP between two data points as a function of changes in physical activity among adolescents (from age 12 to 15) using GEE. They reported that changes in physical activity were inversely related to changes in BP.(214) The only study that applied GEE to three data points for BP found that for every increase of 100 METS in self-reported physical activity per week, SBP decreased by 1.5 mmHg. For every increase of 10 hours of intense physical activity, BMI declined by 0.2 units. However, BP and BMI were used as separate outcomes in this study and the mediation of the relationship between physical activity and BP by BMI was not considered.(215)

It may be difficult to assess the role of adiposity in the association between physical activity and BP. BMI is an indicator of weight, adjusted for height, and is considered to be a good indicator of adiposity in youth.(223) From birth to adulthood, BMI is closely correlated with weight and moderately correlated with height.(224) For youth under 18 years of age, the definition of BMI is sex and age specific. In 532 adolescents age 15-17 years, BMI was highly correlated with other indicators of adiposity such as triceps skinfold thickness, body fat percentage, and waist and hip circumference.(225) Longitudinal studies indicate that declines in self-reported physical activity were inversely related to BMI,(212) and that BMI was a strong predictor of BP in youth, independent of physical activity.(70) Since the inclusion of BMI often attenuated the association between physical activity and BP in some cross-sectional studies in youth,(226, 227) it has been hypothesized that the relationship between these two variables is mediated, at least in part, by adiposity.(152)

However, BMI does not discriminate between changes in muscle versus fat mass. Moreover, changes in body composition in children over time are poorly reflected by changes in BMI.(223, 228) This is because, unlike in adults, increases in BMI with age in children age 8 to 18 years are primarily related to increases in lean (fat free) mass rather than fat mass.(229, 230) Since body weight often increases with increased exercise in children as a result of gains in muscle mass, adjusting for BMI may not be sufficient to remove the confounding effect of body weight in the association between physical activity and BP. It is therefore important to include other indicators of adiposity, in addition to BMI, when studying the associations between physical activity and BP.(223) Indeed, in a recent cross-sectional European study, physical exercise showed a significant and graded relationship with waist circumference and the sum of skinfolds in 4,072 youth aged 9 to 15 years from Denmark, Portugal, Estonia, and Norway.(231)

Dual-energy X-ray absorptiometry (DXA) scans the body with X-rays using a different level of attenuation while passing through fat and lean tissue. DXA is currently considered one of the best methods for assessing body composition. However, data from large-scale, population studies that use DXA scanners to measure body fat are only beginning to emerge because DXA scanners are expensive, difficult to transport, and measurements are time-consuming. A measure of body fat can also be obtained by assessing the skinfold thickness using calipers at different sites on the body such as biceps, triceps, suprailiac, and subscapular regions. Intra-abdominal, visceral adiposity (trunk fat) is more related to BP in youth than peripheral, subcutaneous adiposity (limb fat).(223, 232) When the relationship between body composition and BP was examined in a sample in 920 healthy youth aged 5 to 18 years, adjusting for pubertal status using Tanner stages, trunk fat, assessed by both DXA and skinfold thickness, was significantly and positively associated with SBP and DBP in boys at all pubertal stages in all 3 races (African-American, Asian, and Caucasian) but not in girls.(233) Cross-sectional associations between body fat and BP in 4223 youth aged 5 to 24 years in the Bogalusa Heart Study showed that centrally located fat (subscapular skinfolds) had a stronger relationship with SBP and DBP than peripheral fat (triceps skinfolds). The difference in SBP between the lowest and highest quartile of subscapular skinfolds was 8.5 mmHg (i.e., 100.4 to 108.9 mmHg). In girls, the correlations between subscapular skinfolds and SBP were lower during adolescence (r=0.12), and became non-significant after age 18 years. They remained significant in boys (r=0.17).(234) Finally, fat mass was more closely related to accelerometer-assessed physical activity (minutes of moderate-to-vigorous and vigorous physical activity) than fat-free mass (which was obtained from equations using BMI and triceps skinfolds) in a random sample of 1,553 grade 6 girls from 36 U.S. schools.(235)

Based on experiments that calibrated skinfolds against hydrodensiometry (a method that measures whole body volume by under-water weighing), several equations have been developed to convert BMI and skinfold thickness measures into estimates of body fat.(236, 237) This work was undertaken in small, clinical samples of primarily Caucasian children and the equations are not reliable in heterogeneous populations of children with a wide range of fat mass and body composition.(238) Similar to BMI, they overestimate percent body fat in overweight and obese children.(239) For example, using mixed regression models controlling for baseline body composition, Stevens et al. (2004) demonstrated that higher physical activity levels in 454 second grade children were associated with lower percentage body fat (obtained from prediction equations) three years later in normal weight, but not in overweight children.(240) While methods based on both BMI and skinfold thickness may be useful for estimating percent body fat,(236, 237, 239) these prediction equations significantly underestimate percent body fat during adolescence.(241)

Waist circumference is easy to measure and reproduce, and is considered to be an indicator of visceral or central adiposity. Waist circumference and BMI had the strongest association with SBP in a cross-sectional sample of 155 Native American youth aged 5 to 18 years, while measures of biceps, triceps, suprailiac, and subscapular skinfold thickness did not.(242) Similarly, waist circumference was more highly correlated with SBP and DBP in 818 pre-pubertal children aged 3 to 11 years than BMI or triceps and subscapular skinfolds.(243) Waist circumference has in fact been recently advocated as a better adiposity indicator and a more important predictor of BP and CVD risk in youth than BMI. While both BMI and waist circumference were able to discriminate hypertensive from non-hypertensive children (i.e., the areas under receiver operating characteristic curves were 0.84 and 0.76, respectively) in 4,177 children 5 to 11 years old, waist circumference is better than BMI in identifying hypertension in obese children.(244) However, no longitudinal studies to date have used multiple indicators of adiposity (BMI, waist circumference and skinfold thickness) to assess the role of changes in adiposity in the association between physical activity and BP in youth.

The second objective of this thesis is to examine the longitudinal association between changes in physical activity and BP in youth, and to assess whether this association is mediated by changes in adiposity. To address this objective, I will use multiple data points for physical activity and several indicators of adiposity, including BMI, waist circumference, and skinfold thickness.

Challenges in maintaining healthy levels of physical activity

The key to effectiveness and sustainability of behavioural, lifestyle changes required to prevent weight gain (or regain) and higher BP in both adults and youth is long-term adherence to increased levels of physical activity.(47, 51) Sustained levels of physical activity are required for continued benefit based on the observation that the effect of physical activity on blood pressure in clinical populations of youth was often transient.(180) Although obesity prevention interventions were able to improve physical activity levels in non-clinical populations of youth,(181) these improvements were short-term and were not sustained in the long run. A Cochrane review of 19 adult studies published before December 2004 found improvements in physical activity levels in the short- to mid-term but not in the long-term.(245) Tate et al. (2007) conducted a randomized controlled trial comparing average/normal physical activity levels (1000 kcal physical activity/week) with high levels of physical activity (2500 kcal physical activity/week) in 202 overweight adults. After 18 months of intervention, individuals assigned to the latter group were engaging in higher levels of physical activity. However, physical activity levels declined to their original levels one year after the end of the program, at which point there were no differences between the groups.(246) These studies demonstrate that most individuals relapse from adherence to high levels of physical activity, and adherence to a prescribed exercise regime remains a challenge.

Despite current recommendations for children and adolescents to accumulate at least 90 minutes of moderate-to-vigorous physical activity over the course of the day, in bouts of at least 5 to 10 minutes,(149) less than 10 percent of Canadian youth aged 5-19 years attain these current recommendations.(149, 150) Assessment of adherence to Canadian physical activity guidelines in 251 children age 8 to 11 years, found that only 4 percent accumulated 90 minutes of more, 12.7 percent accumulated 60 to 89.9 minutes, while 52.2 percent accumulated less than 30.0 minutes and 31.1 percent accumulated 30.0 to 59.9 minutes.(150)

Maintenance programs designed to help individuals sustain long-term improvements in physical activity have also had limited success. Following a 5-month obesity prevention intervention in 204 healthy children aged 7 to 12 years, Wilfley et al. (2007) carried out a randomized controlled trial of a two-year maintenance programs following an initial weight loss intervention. Although the maintenance programs improved short-term weight loss in children, these effects waned over the next one to two years.(247) In an editorial, Rhodes and Ludwig (2007) underscored that the effects of weight loss maintenance interventions were small in the short-term and diminished even further over time.(248)

A high level of physical activity was the primary strategy for over 90 percent of 6,000 adults who successfully maintained in a 30 kg weight loss for 6 years was.(142) Achieving and maintaining increases in physical activity levels is challenging and requires substantial motivation on the part of individuals. Indeed, one of the characteristics that predicted maintenance among these 6,000 individuals was consistent self-monitoring of body weight. Similarly, a meta-analysis of 64 interventions aimed at preventing weight gain in children and adolescents found that 21 percent produced significant effects, with larger effects reported in programs of shorter duration. However, one factor that was consistently associated with larger effects was having participants self-select (volunteer) into the intervention.(49) These studies indicate that adults and youth who have successfully maintained weight loss over the long term were highly self-motivated to do so a priori.

While the classic components of prevention and treatment interventions in clinical and non-clinical populations of youth often included health education, improvements in diet, and increases in physical activity levels,(87, 186) the key to long-term success is the motivation on the part of individuals to embrace lifestyle changes required to lose weight and to engage in increased levels of physical activity regularly. One component of effective behavior change may be recognition on the part of the individual that their weight status exceeds normal weight and poses a health risk. I argue that recognition of overweight on the part of individuals may be an important component of intervention strategies targeting behaviour modification such as increased physical activity and weight loss. Since accurately perceiving oneself as overweight or obese is considered an important cue for action and change, and has been linked to greater motivation to engage in healthy lifestyle behaviors,(249, 250) individuals, be they children or adults, may need to perceive themselves to be at risk and recognize their overweight status as a health problem in order to change their lifestyle behaviors.

However, growing evidence suggests that actual weight and perception of weight status often do not coincide, and that deviations between actual and perceived weight status are more common among overweight and obese individuals.(251-

254) Among overweight adults, 43 percent of men and 18 percent of women perceived themselves to be of "healthy weight or underweight".(251-253) Among overweight youth, 58 percent of boys and 34 percent of girls perceived their weight to be "about right".(254) These studies underscore that significant proportions of individuals misperceive their overweight status.

Misperception of overweight may be one explanation for the limited success of prevention interventions aimed at modifying lifestyle behaviours. This hypothesis is premised on theoretical models of health behaviour change. Specifically, the Health Belief Model (255), the Transtheoretical Model of Health Behaviour Change (256), and the Decisional Balance Model(257, 258) have each emphasized the necessity of perceiving oneself "at risk" for behaviour change to be possible. When individuals misperceive their actual weight status and do not consider themselves to be overweight or obese, a fundamental impetus for long-term adherence to increased levels of participation in physical activity may therefore be lacking in the overweight children and adolescents. Individuals are then less likely to heed public health messages about the risks of obesity or be receptive to obesity prevention interventions that require lifestyle behavior modifications. I provide a brief review of each of these theoretical frameworks in the next section.

Theoretical frameworks for understanding behaviour modification

According to the Health Belief Model,(255) the motivation for behavioural change is based on an individual's perception of susceptibility to "risk" and severity of the "risk", combined with the perceived benefits as well as barriers to undertaking a new action or behavioural change to avoid the "risk". Rosenstock (1988) outlined four constructs/concepts to account for readiness to change an unhealthy behaviour: perceived susceptibility (i.e., the perception of "risk" in developing a health problem), perceived severity (i.e., concern about developing a disease), perceived benefit (i.e., belief in the effectiveness of the change necessary to reduce the "risk" of disease), perceived barriers (i.e., cognitive consideration of the pros and cons of adopting new behaviour).(255) Implicit in each of these is the concept of cues to action that provide stimuli for readiness to change. According to the Health Belief Model, an individual has to perceive that he/she is at "risk" in order to modify or change their behaviour.

The Transtheoretical Model of Health Behaviour Change posits that individuals progress though a sequence of stages (pre-contemplation, contemplation, planning and preparation, action, and maintenance), each of which must be completed (gone through) before reaching their final behaviour goal.(256) Consistent with the Health Belief Model, actively considering changing one's behaviour is a prerequisite for action and behaviour change.

The Decisional Balance Model refers to a rational decision-making process in which an individual assesses the advantages (pros) and disadvantages (cons) of changing their behaviour.(257, 258) Since the Transtheoretical Model of Health Behaviour Change lacks the motivational stimulus that would necessitate moving from stage to stage, the Decisional Balance Model has become a critical component of the Transtheoretical Model of Health Behaviour Change and considered together, they enhance our understanding of behaviour change. The pros and cons in the Decisional Balance model serve as valuable determinants for evaluating progression through the stages of the Transtheoretical Model. When examining changing 12 behaviours (smoking cessation, quitting cocaine, weight control, high-fat diets, adolescent delinquent behaviours, safer sex, condom use, sunscreen use, radon gas exposure, exercise acquisition, mammography screening, and physicians' preventive practices with smokers), Prochaska et al. (1994) found that for all 12 behaviours when individuals were in the pre-contemplation stage the cons of changing behaviour significantly outweighed the pros, while in the action stage the pros of maintaining behaviour exceeded the cons of reverting to the initial habit.(258)

The Social Cognitive Theory posits that individuals acquire behaviour in part by observing others whether in direct social interactions or indirectly through media.(259) The environment in which children grow up has influence on behaviour development. Parents, peers, and educators play an important role in this cognitive learning process as children acquire behaviours by imitating the behaviours of others in their immediate environments. Brown and Ogden (2004) demonstrated significant correlations in eating attitudes and behaviours between parents and their children.(260) The Social Cognitive theory has been a popular underpinning in the design of obesity prevention interventions in youth (Table 2.2). Cole et al. (2006) described the theoretical and methodological characteristics of school-based obesity prevention interventions that used healthy lifestyle education, dietary habits, and/or physical activity in children aged 4 to 14 years. The Social Cognitive Theory was the stated or implied theory in eight of the 10 studies. Providing healthy lifestyle education as part of obesity prevention interventions did not, however, improve the limited success of obesity prevention interventions in youth.(186)

Taken together, the fundamental tenet of these health behaviour change models is that individuals must perceive that there is a problem (or risk of a problem) before behaviour change can occur. Thus, the causal model underlying behaviour change is such that in order to even consider changing their lifestyle habits and behaviours, youth must perceive reality correctly. Without correct perceptions, it is unlikely that youth will perceive a need to change, without which preventive efforts may not be successful.

For obesity prevention, acknowledgement of excess weight has been hypothesized to improve motivation among youth and their parents to engage in healthy lifestyle behaviors.(249, 250) Indeed, Canadian clinical practice guidelines on the prevention and management of obesity in children and adults recommend assessing readiness and barriers to change, prior to implementing a healthy lifestyle plan for weight control or management.(47) A recent application of the Transtheoretical Model demonstrated that the majority of children and adolescents were not ready for an obesity prevention intervention.(261) Not only were they not participating in healthy lifestyle behaviors, they did not meet national recommendations for physical activity, or for fruit and vegetable consumption, and most did not realize they needed to adopt these healthy behaviors. Indeed, healthy lifestyle behavior changes may be more likely to occur if youth recognize themselves as overweight or obese.

It is unclear what factors influence misperception of weight status. Previous studies were limited to cross-tabulations of weight status and BMI categories, and thus, were unable to evaluate the determinants of misperception. It is plausible that youth may underestimate their weight status when they are exposed to overweight/obese people in their immediate environments at home and in school, resulting in a perceptual bias. In other words, when children's parents and schoolmates are overweight or obese, their own overweight status may seem normal by comparison. Recent evidence indicates that having a social network with a high prevalence of overweight is associated with weight gain among adults.(262) An obesogenic environment at home, defined as an environment that promotes excessive food intake and discourages physical activity,(263, 264) has been linked to adolescent weight status.(265, 266) Adolescents who live in families that permit or model behaviors associated with excessive weight (e.g., poor diet, physical inactivity, considerable television viewing) are at increased risk of overweight and obesity in young adulthood.(266) However, little is known about how social contexts (e.g., school) influence misperception of weight status among youth. No research to date has examined whether exposure to overweight/obese people among those at home and in school is associated with greater misperception of weight status, such that children and adolescents who live with overweight parents and attend schools with overweight schoolmates are more likely to misperceive (or underestimate) their weight status.

The third objective of this thesis is to assess the extent to which children and adolescents' perception of their weight status does not concur with measured weight, and whether weight misperception is associated with exposure to overweight/obese people at home or in school.

Although acknowledging excess weight may motivate action and change, no study has yet investigated if youth who do not recognize themselves as being overweight or obese are less likely to engage in physical activity.

The fourth objective of this thesis is to examine if weight status misperception among youth is associated with the level of participation in physical activity.

Summary

With rising levels of childhood obesity and declining levels of physical activity in youth, increased understanding of the associations between physical inactivity, obesity and BP has high public health importance.(213) Preventive interventions in non-clinical populations of youth have had limited success but it may be premature to discount the benefits of physical activity for the prevention of weight gain and BP increases in youth.(172, 213) There remain gaps in our understanding of how declines in physical activity during childhood and adolescence relate to BP in non-clinical populations of youth and, because many studies were short-term, the long-term effects of physical inactivity on weight gain and BP need investigation. Moreover, it remains unclear whether recognition of one's own overweight status plays a role in levels of physical activity in youth. Since lifestyle habits and behaviours develop at an early age, preventive strategies that focus on fostering healthy lifestyle behaviours from childhood through adolescence and into adulthood are likely to have the highest potential for preventing weight gain and BP increases with age.

Chapter 3: Study objectives

The general aim of this thesis is to improve understanding of the role of physical activity in the prevention of elevated BP in youth. The following four objectives are interconnected to achieve this overall goal.

1. The first objective is to assess the sex-specific impact of changes in height and indicators of adiposity such as BMI, waist circumference, and skinfold thickness, on SBP increases with age during adolescence.

We hypothesized that, despite recent evidence that sex differences in SBP increase with age are established at an early age, these differences are due to differences in contemporaneous changes in growth parameters between boys and girls. If sex differences in SBP increases during adolescence are attributable to differences in height and body weight between boys and girls, results will underscore that gaining weight is equally detrimental to BP in both boys and girls.

2. The second objective is to examine the longitudinal association between changes in physical activity and BP in youth, and to assess whether this association is mediated by changes in adiposity, using multiple data points for physical activity and several indicators of adiposity, including BMI, waist circumference, and skinfold thickness.

We hypothesized that declines in physical activity during adolescence are detrimental to BP in youth, independent of changes in weight and other indicators of adiposity. If declines in physical activity are related to BP in youth, prevention of declines during adolescence may be an important prevention strategy for preventing higher BP in youth.

3. The third objective is to assess the extent to which children and adolescents' perception of their weight status does not concur with measured weight, and whether weight misperception is associated with exposure to overweight/obese people at home or in school.

We hypothesized that misperception of weight status would be more prevalent/common among overweight and obese youth and that misperception would be greater among those exposed to overweight and obesity at home and in school. If youth who are exposed to overweight and obesity at home and in schools when their parents and schoolmates have higher BMI, are more likely to underestimate their weight status, helping youth recognize they are at risk and correct their misperceptions may be an important component of obesity prevention interventions.

4. The fourth objective is to examine if weight status misperception among youth is associated with the level of participation in physical activity.

We hypothesized that youth who do not recognize themselves as being overweight or obese may be less likely to engage in physical activity. Misperception of overweight may therefore hinder the success of obesity prevention interventions. Prevention interventions that aim to encourage participation in physical activity among youth may need to incorporate components to address misperception of weight status.

Adolescence is particularly well-suited for the study of this relationship since it is a period of rapid growth and behavioural changes when BP, height, weight and body fat increase rapidly (53, 54) and physical activity levels decline sharply.(55-57) In addition, unlike many adults, adolescents have not yet developed chronic health conditions which could confound the association between physical activity and BP. Moreover, while the causes of elevated BP before age 11 years are generally attributable to renal disease or other medical causes, elevated BP after age 11 years is usually not associated with an underlying disease (and is thus referred to as essential hypertension). An analysis of 56 monozygotic and 29 same-sex dyzogotic twin pairs of 13 year old adolescents found the genetic variance for SBP to be high, indicating that the genetic influence on BP in adolescence was moderate at best.(267) Indeed, lifestyle and behavioural factors are considered to be the most likely determinants of elevated BP in adolescence.(78) For example, recent evidence suggests that the effect of change in relative body size on adult BP was more pronounced after age 11 years, indicating that increases in body size prior to age 11 years are less harmful to adult BP than increases occurring after this age.(268)

Although I conducted analyses for both SPB and DBP, I focus on SBP throughout this thesis for several reasons. SBP is thought to be a more important contributor to the global burden of disease attributable to hypertension than DBP.(6, 7, 269) SBP is also a major criterion for the diagnosis, staging, and treatment of hypertension in adults,(269) and some evidence exists that this is true in children. Increases in SBP in children are more closely associated with left ventricular hypertrophy than DBP,(270) highlighting the need to focus on normalization of SBP in childhood and adolescence for the prevention of elevated BP and CVD in adulthood. SBP also has greater measurement accuracy and reproducibility than DBP, particularly in youth.(102) In children and adolescents, the vast majority of elevated BP is in fact elevated SBP.

Chapter 4: Methods

Data sources

Two sources of data were used in this thesis. Objectives 1 and 2 were addressed using the Natural History of Nicotine Dependence in Teens (NDIT) Study, 1999-2011. Objectives 3 and 4 were addressed using the Québec Child and Adolescent Health and Social Survey. I describe each of these two data sources in turn.

The Natural History of Nicotine Dependence in Teens (NDIT) Study, 1999-2011 is an ongoing prospective cohort of 1293 grade 7 students recruited in Fall 1999 in a convenience sample of 10 public secondary schools in Montréal. Schools were selected in consultation with local boards and school principals to include a mix of French and English schools, urban, suburban, and rural areas, and high and low socioeconomic neighbourhoods. Thirteen schools were invited to participate. While all schools agreed, two were excluded because of a low return rate of consent forms and one because school administration could not guarantee long-term cooperation. Data collected in one school lagged by one year such that students in that school were in grade 7 in 2000-2001 school year. Over half (55.4 percent) of eligible students participated at baseline; the relatively low response was related to the need to take blood samples for genetic analysis and a province-wide labour dispute that resulted in some teachers refusing to collect consent forms. At the time of the baseline data collection in Fall 1999/Winter 2000, students were 12-13 years old on average.

Students completed questionnaires at school every 3 months during the 10-month school year (September to June) in English or French according to the language of instruction of each school from 1999 to 2004. The questionnaires were translated from English into French and then back-translated, with adjustments made when the back-translation indicated that the meaning was divergent. The NDIT Study provides follow-up data on physical activity, sedentary behaviour, smoking and alcohol consumption, psychosocial variables, and family background factors, with questionnaires including more than 70 questions.

Data continue to be collected in 2009; the participants are currently 22-23 years old. Data from the first five years of follow-up (1999/2000-2004) were available for analysis, so that each student had up to 20 questionnaires available. For objectives 1 and 2, I limited analyses to information obtained in 19 waves of data collection in the first five years of follow-up.

Blood pressure (systolic and diastolic) and anthropometric measurements (height, weight, waist circumference, and triceps and subscapular skinfold thickness) were measured three times (wave 1 at baseline in Fall 1999/Winter 2000, wave 12 in Spring 2002, and wave 19 in Spring 2004) by technicians trained and certified according to a standardized protocol.(271) For the one school that lagged in data collection by 1 year, blood pressure and anthropometric measurements were measured in Fall 2000, Spring 2003, and Spring 2005. Physical activity was assessed in each of the 19 waves of data collection between 1999/2000 and 2004.

The number of participating students varied among the 19 data collection waves (Table 1). Of 1293 students, 424 (32.8 percent) were lost to follow-up because they either refused to continue to participate (n=83) or moved (n=341) during the first five years of follow-up.

The Québec Child and Adolescent Health and Social (QCAHS) Survey was a provincially representative, school-based survey of Québec youth. The QCAHS Survey target population was children and adolescents aged 9, 13, and 16 years on March 31, 1999 attending schools in Québec. The sampling frame consisted of the 1998 to 1999 Québec Ministry of Education student roll, which included all students attending schools in Québec. Students attending federal government schools, native schools, schools in very remote regions, schools in which more than 50 percent of youth were handicapped and schools with fewer than 12 students of the specified ages were excluded. The final sampling frame contained 97 percent of all 9, 13, and 16 year old youth in Québec.

The QCAHS Survey was a multistage, stratified, cluster sample of Québec youth. Independent samples were drawn for each age. Of 17 administrative regions of Québec, 13 were selected for the next sampling stage. Within each administrative region, approximately 60 schools were randomly selected for each age group using three levels of stratifications according to the language of instruction (French or English), public or private school status (only for French schools), and geographic location based on metropolitan census areas. Within each school, random samples of 25 students stratified according to sex were selected. A sample size of 1500 in each age group was targeted. The final sample included 3665 participants (age 9, n = 1267; age 13, n = 1186; age 16, n = 1212) from 178 schools, with response proportions of 83, 79 and 78 percent in each age group, respectively.

The QCAHS Survey was developed to assess the general health and social well-being of youth in Québec, with the questionnaire covering a range of topics. Data collection was conducted between January and May 1999. Data were collected in age-adapted, self-report questionnaires for children and adolescents administered at school in a three-hour morning session, and a self-report parent questionnaire administered at home, which assessed the family and social environment, parental education, and other socio-demographic information. Anthropometric and biological measurements were collected at school by ten teams of pediatric nurses, kinesiologists, and trained interviewers.(272) A total of 1049, 1170 and 1144 students of age 9, 13 and 16 years from 69, 104 and 61 schools, respectively, had data on weight status misperception and were available for the analysis.

NDIT Study measures

Blood pressure

Blood pressure was assessed in the sitting position, on the right arm after voiding and a five-minute rest period with an automated oscillometric device (Dinamap XL, model CR9340, Critikon Co.) by technicians trained and certified according to a standardized protocol.(273) Oscillometric devices were calibrated against a mercury sphygmomanometer before each data collection period. In a validation study in 52 youth aged 8 to 16 years with a BMI range of 15-45 kg/m^2, there were no systematic differences between readings obtained with the Dinamap, which was used in NDIT Study, and mercury sphygmomanometers.(32)

A minimum of three blood pressure readings were recorded for each student at one-minute intervals. If the difference between the second and third readings was greater than 20 mmHg and 10 mmHg for systolic and diastolic blood pressure respectively, forth and fifth readings were taken. To reduce blood pressure reactivity/habituation (i.e., "white coat" effect), the first reading was not considered.(114) The mean value of the two readings with the least difference was calculated from the remaining readings.

Anthropometry

Anthropometric measurements were collected with students dressed in light clothing without shoes using a stadiometer (model 214 Road Rod, Seca Corp.) for height, a scale (floor model 761, Seca Corp.) for weight, Lange-type Baseline Skinfold calipers (AMG Medical Inc.) for skinfold thickness, and a standard tape measure (placed just above the uppermost border of the right ilium at the end of normal expiration) for waist circumference. Measurements were recorded to the nearest 0.1 cm for height, 0.2 kg for weight, 0.1 cm for waist circumference, and 0.5 mm for skinfold thickness. Two measurements were obtained for each participant. A third measurement was taken if the difference between the first two measurements was greater than 0.5 cm for height, 0.2 kg for weight, 0.5 cm for waist circumference, and 1 mm for skinfold thickness. All anthropometric measurements were repeated systematically in every tenth student to assess inter-rater reliability (ICC=0.99 for height and weight, 0.98 for waist circumference, and 0.95 for triceps and 0.96 for subscapular skinfold thickness). For all anthropometric measurements, the mean value of the two measurements with the least difference was calculated. BMI was computed as weight/height^2 (kg/m^2). Skinfold thickness was the sum of triceps and subscapular skinfold thickness.

Physical activity

Students completed a 7-day recall checklist that asked them to report for each day of the preceding week (Monday to Sunday) each activity they engaged in for ≥5 minutes outside the regular school gym class. The checklist was adapted from the Weekly Activity Checklist (274) to reflect common activities engaged in by adolescents in Montréal. The original instrument correlated with accelerometer-measured physical activity in youth ($r=0.34$, $p<0.01$) and its 3-day test-retest reliability was $r=0.74$.(275) The test-retest reliability of the adapted checklist was examined in a NDIT Study subsample of 76 students, who completed it twice two weeks apart. The correlation between repeated measures was $r=0.73$, which is comparable to the correlation of $r=0.76$ observed with repeated measures using accelerometers in youth.(276) The adapted checklist also showed evidence of convergent-construct validity against energy intake.(277) The number of MVPA sessions per week was the sum of 23 activities,(278) defined as activities with estimated energy costs over 4.8 metabolic equivalent values,(279-281) including bicycling, swimming/diving, basketball, baseball/softball, footfall, soccer, racket sports, ice/ball hockey, jumping rope, downhill skiing, cross-country skiing, ice skating, rollerblading/skateboarding, exercise/physical conditioning, ball playing, track and field, playing games, jazz/classical ballet, outdoor play, karate/judo/tai chi, boxing/wrestling, mixed walking, running/jogging.

QCAHS Survey measures

Misperception of weight status

Perceived weight status

Self-reports of current weight status were obtained using the Stunkard Body Rating Scale,(282) a visual analogue scale consisting of seven sex-specific silhouettes of the same height, with weight ranging from underweight to obese. Participants selected the figure they perceived best corresponded to their current appearance.

Actual weight status

Height and weight were assessed with students dressed in light clothing without shoes. Height was measured with a standard measuring tape during maximal inspiration and weight was measured with a spring scale that was calibrated daily using a set of standard weights. Measurements were recorded to the nearest 0.1 cm for height and 0.2 kg for weight. Two measurements were obtained for each participant. A third measurement was taken if the first two differed by more than 0.5 cm for height and 0.2 kg for weight.(272) The mean value of two measurements with the least difference was used for data analyses. BMI, calculated as weight/height^2 (kg/m^2), was used as a measure of actual weight status.

Weight status misperception

Although the Stunkard Body Rating Scale is not directly matched to BMI percentiles, the silhouettes are highly correlated (r=0.7) with BMI percentiles.(283, 284) To assess misperception of weight status, deviation of perceived weight status from the actual weight status was obtained in the following three-step approach:

1) Values from the seven-item visual analogue scale (Stunkard Body Rating Scale) of perceived weight status were assigned Z-score values (-3, -2, -1, 0, 1, 2, 3) such that the three middle silhouettes (-1, 0, 1) were thought to represent "normal" body weight, while the remaining silhouettes represented the overweight and underweight categories, respectively.
2) BMI values were transformed into Z-scores using age- and sex-specific cutoffs from the 2000 Centers for Disease Control and Prevention (CDC) pediatric growth charts as a reference population.(285) The standardized BMI score indicates how many standard deviation units a child's BMI is from the mean BMI of the reference group for their age and sex.
3) Misperception of weight status was calculated as the arithmetic difference between the perceived weight Z-score and the BMI Z-score: [Misperception = $Z_{\text{Perceived weight}} - Z_{\text{BMI}}$].

Positive deviation units of the misperception measure indicated an overestimation of weight status (i.e., participants perceived themselves to be heavier than their measured BMI). Negative deviation units of the misperception measure indicated an underestimation of weight status (i.e., participants perceived themselves to be thinner than their measured BMI).

Exposure to overweight/obesity at home: Parent weight status

Self-report of height and weight was provided by the parent completing the questionnaire (78 percent of parent questionnaires were completed by mothers). BMI values were calculated as weight/height^2 (kg/m^2).

Exposure to overweight/obesity in school: Schoolmate weight status

Schoolmate weight status was calculated as the average BMI of all QCAHS Survey students attending the participant's school. Thus, an aggregate BMI was created for each school. On average, there were 20 students per school in 178 schools; ranging from 11 to 43 students per school.

Physical activity

Students completed a 7-day recall checklist that asked them to report for each day of the preceding week (Monday to Sunday) each physical activity they had engaged in for at least 15 minutes without interruption. The checklist was adapted from the Weekly Activity Checklist (274)to reflect common activities engaged in by children and adolescents in Québec. The original instrument correlated with accelerometer-measured physical activity in youth (r=0.34,

$p<0.01$) and its 3-day test-retest reliability was $r=0.74$.(275) The number of physical activity sessions per week was the sum of 17 activities youth engaged in outside their regular physical education classes at school during the previous 7 days.

Statistical analyses

Objective 1

For the first objective, the repeated SBP measurements in 1999/2000, 2002, and 2004 were analyzed using sex-specific individual growth modeling. I fitted two-level individual growth models to account for the non-independence of observations inherent in longitudinal data with repeated measures on the same individual. Intra-individual correlation (intra-class correlation, ICC) for blood pressure in the same individual was 0.68 in NDIT Study, indicating that the "closeness" of observations within the same individual relative to the "closeness" of observations between different individuals was relatively high. This is equivalent to saying that blood pressure in the same individual tracks over time. Below I provide a brief description of the individual growth models.

<u>Individual growth models</u>

This analytic approach assumes that each student has a different linear change/increase in SBP with age. It estimates the average change in SBP over time (fixed effect of time) and the variation in SBP initial levels and rates of change that vary randomly between students (variance components). It can also account for time-varying predictors of the linear change/increase in SBP, by including such factors as height and adiposity indicators as covariates.

Individual growth models allow us to answer the following questions: What are the average blood pressure levels at age 12 years (baseline) in boys and girls and how much do these levels vary between individuals? How much does blood pressure change over five years, on average, and how much do these rates of change vary between individuals? How much of the between-individual variation in initial levels and rates of change can be ascribed to changes in height and adiposity indicators, or to random error variation? For example, individual A has SBP level of 100 mmHg at age 12 and SBP increases, on average, by 4 mmHg per year to 120 mmHg 5 years later. Individual B has initial SBP level of 120 mmHg and SBP increases, on average, by 8 mmHg per year to 160 mmHg 5 years later. Thus, individual B has a higher initial level and his SBP increases at a faster rate than for individual A. Individual growth models also allow us to estimate which time-varying covariates are associated with initial levels and rates of change in blood pressure. For example, if participant A had a BMI of 20 kg/m^2, while participant B had a BMI of 25 kg/m^2, initial SBP level for participant B is expected to be higher and to increase at a faster rate than for participant A. In addition, a BMI increase from 25 to 30 kg/m^2 over 5 years than for individual B and from 20 to 25 kg/m^2 for individual A could be associated with increases of 40 mmHg and 20 mmHg individuals B and A, respectively.

The individual growth models take the following general form:

$$SBP_{ij} = [\gamma_{00} + \gamma_{10}(Age_{ij})] + [\zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}]$$

$$\underbrace{\phantom{\gamma_{00} + \gamma_{10}(Age_{ij})}}_{\substack{\text{structural part} \\ (\textit{fixed}\text{ effects})}} \qquad \underbrace{\phantom{\zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}}}_{\substack{\text{stochastic part} \\ (\textit{random}\text{ effects})}}$$

structural part stochastic part

(*fixed* effects) (*random* effects)

SBP_{ij} – blood pressure value for the i^{th} student at j^{th} measurement occasion

Age_{ij} – student's age measured from age 12

γ_{00} – population average initial level at t=0 (age 12)

γ_{10} – population average rate of change

ζ_{0i} – individual variation around population average initial level

ζ_{1i} – individual variation around population average rate of change

This model can also be written as a specification for each level of change

Level-1 model: within-individual change

$SBP_{ij} = \beta_{0i} + \beta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Level-2 model: between-individual differences in change

$\beta_{0i} = \gamma_{00} + \zeta_{0i}$

$\beta_{1i} = \gamma_{10} + \zeta_{1i}$

All models are subject to normality assumptions of components of random variation

$$\text{where} \quad \varepsilon_{ij} \sim N\left(0, \sigma_\varepsilon^2\right) \text{ and } \begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} \sigma_0^2 & \sigma_{01} \\ \sigma_{10} & \sigma_1^2 \end{bmatrix} \right)$$

<u>Analysis</u>

I fitted the following six models to assess the sex-specific impact of changes in height and indicators of adiposity such as BMI, waist circumference, and skinfold thickness, on SBP increases with age during adolescence:

Model 1: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 2: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 3: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \beta_{30}(BMI_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 4: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \beta_{30}(Waist_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 5: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \beta_{30}(Triceps_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 6: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \beta_{30}(Subscapular_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$

Model 1 included the effect of time and two sources of variation – between- and within-student variation. Variance between students was further decomposed into variance in initial levels and in rates of SBP change. To assess whether changes in SBP over five years and variation in change patterns between students could be attributed to changes in height, Model 2 included the time-varying effect of height. Each adiposity indicator was then added to Model 2 separately (BMI in Model 3, waist circumference in Model 4, and triceps and subscapular skinfold thickness in Models 5 and 6). The effect of BMI, waist circumference, and measures of skinfold thickness could not be tested simultaneously due to multicollinearity.

Student's age represented time and height was included in the models as a crude proxy measure of the maturation process. Models 1-6 were sex-specific. All associations were adjusted for physical activity (self-reported number of physical activity sessions ≥5 minutes in the past week (preceding data collection) that was averaged over follow-up) and smoking (self-reported number of cigarettes smoked in the past week that was averaged over follow-up). In order to formally test sex differences in these associations, I also estimated models with interactions terms for sex and age, height, BMI, waist circumference, triceps and subscapular skinfold thickness to show which coefficients were statistically different between boys and girls.

For all models, age and anthropometric characteristics were "centered" on their respective minimum values (closest integer) to facilitate the interpretation of the results (age was "centered" on 12 years, height on 130 cm, BMI on 13 kg/m^2, triceps and subscapular skinfold thickness on 4 mm and 3 mm respectively, and waist circumference on 45 cm). "Centering" a variable about its minimum value yields an intercept that is interpreted as an estimate of SBP at that value (e.g., baseline values refer to SBP at age 12), rather than at zero. After examining the correlation structure of residuals adjusted for relevant covariates, an unstructured error covariance structure was specified to reflect the longitudinal nature of the data.

Objective 2

There was no measure of puberty in the NDIT Study and the association between physical activity and SBP may be confounded by pubertal maturation. For the second objective, I divided the follow-up time into two periods corresponding to early (mean age 12.8 to 15.2 years) and late adolescence (mean age 15.2 to 17.0 years) on the premise that the second period may be less confounded by pubertal maturation, particularly in girls. The analysis pertaining to early adolescence was based on SBP and anthropometry data collected in 1999/2000 and 2002, and repeated assessments of MVPA sessions from the 12 waves of data collected during this time. The analysis pertaining to late adolescence was based on SBP and anthropometry data collected in 2002 and 2004, and repeated assessments of MVPA sessions from 8 waves collected during this time. However, since blood pressure change between 2 data points closer in time is likely to be more unstable than blood pressure change between 2 points further apart in time or 3 data points, I adjusted blood pressure levels for intra-individual variability in blood pressure using a "shrinkage factor." I provide a brief description of this approach below.

<u>Shrinkage</u>

Individual growth modeling is based on the Empirical Bayes approach. The conceptual framework underlying this approach improves the precision of individual growth parameter estimates by incorporating information from the population average to reduce (or "shrink") individual estimates observed in the raw individual data toward the population average.(140) In contrast to the “observed” estimates that are based solely on observed data for one participant and do not “borrow strength” from the population average, the “predicted” estimates are conservative as they are based on a weighted average of observed estimates for a particular participant and population average estimates weighted by an inverse of each of the 2 variances derived from the model.(140, 286) (I borrow the terms “observed” and “predicted” from Singer and Willett, 2003).(140)

“Observed” estimates of initial blood pressure level (intercept) and rate of change (slope) *for each participant* can be obtained by fitting least squares linear regression models using the data for one participant only, while “predicted” estimates can be obtained by fitting random effects models using the data from the entire collection of children. A comparison of “observed” and “predicted” estimates of SBP showed that the extent of random error variation in both initial levels and rates of change in SBP was high in NDIT Study (Figures 4.1 and 4.2). Individual growth models “shrunk” the intra-individual variance in SBP substantially.

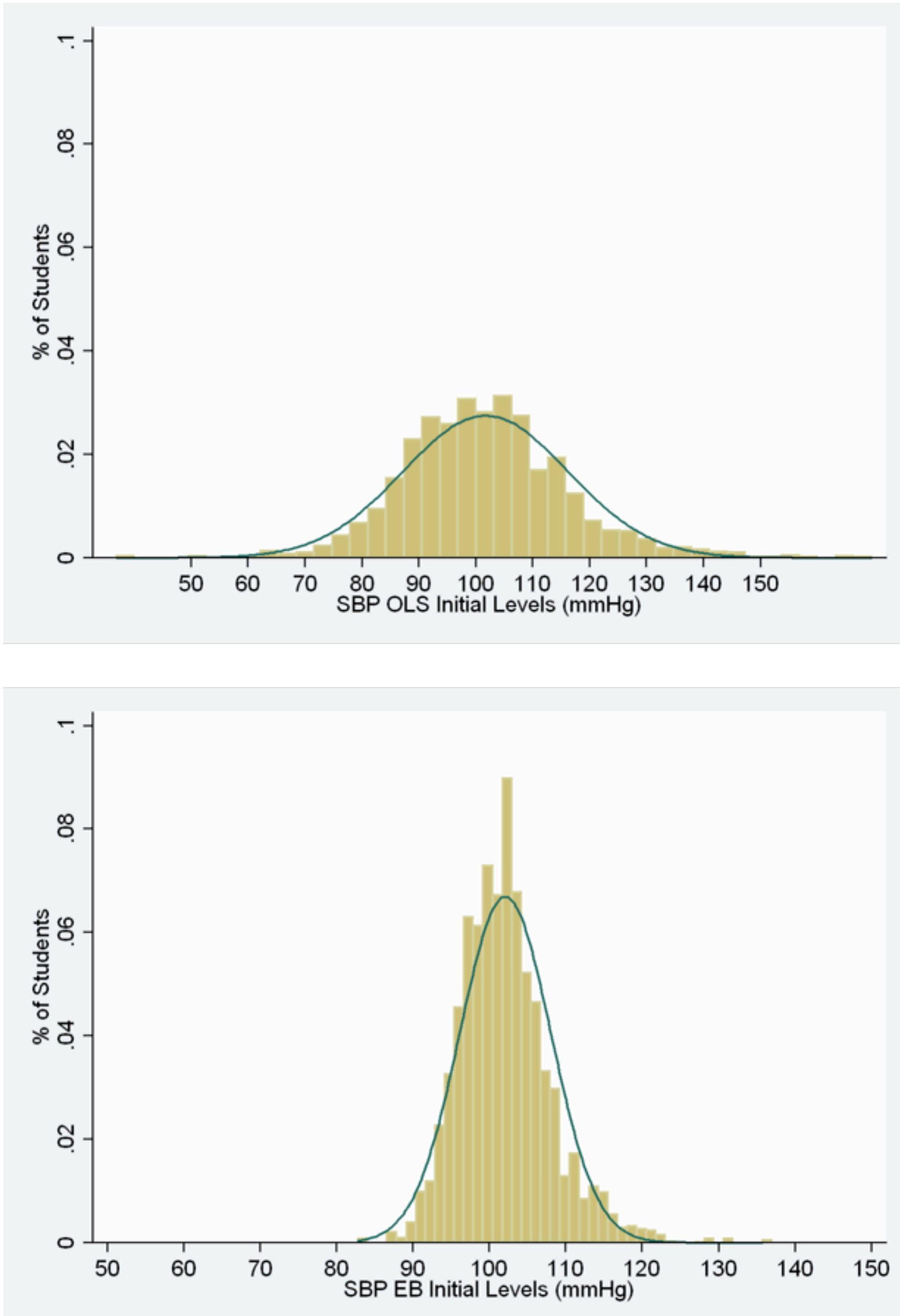

FIGURE 4.1. Distribution of “observed” (OLS) and “predicted” (EB) estimates of initial levels in systolic blood pressure

Abbreviations: OLS, ordinary least squares; EB, empirical Bayes.

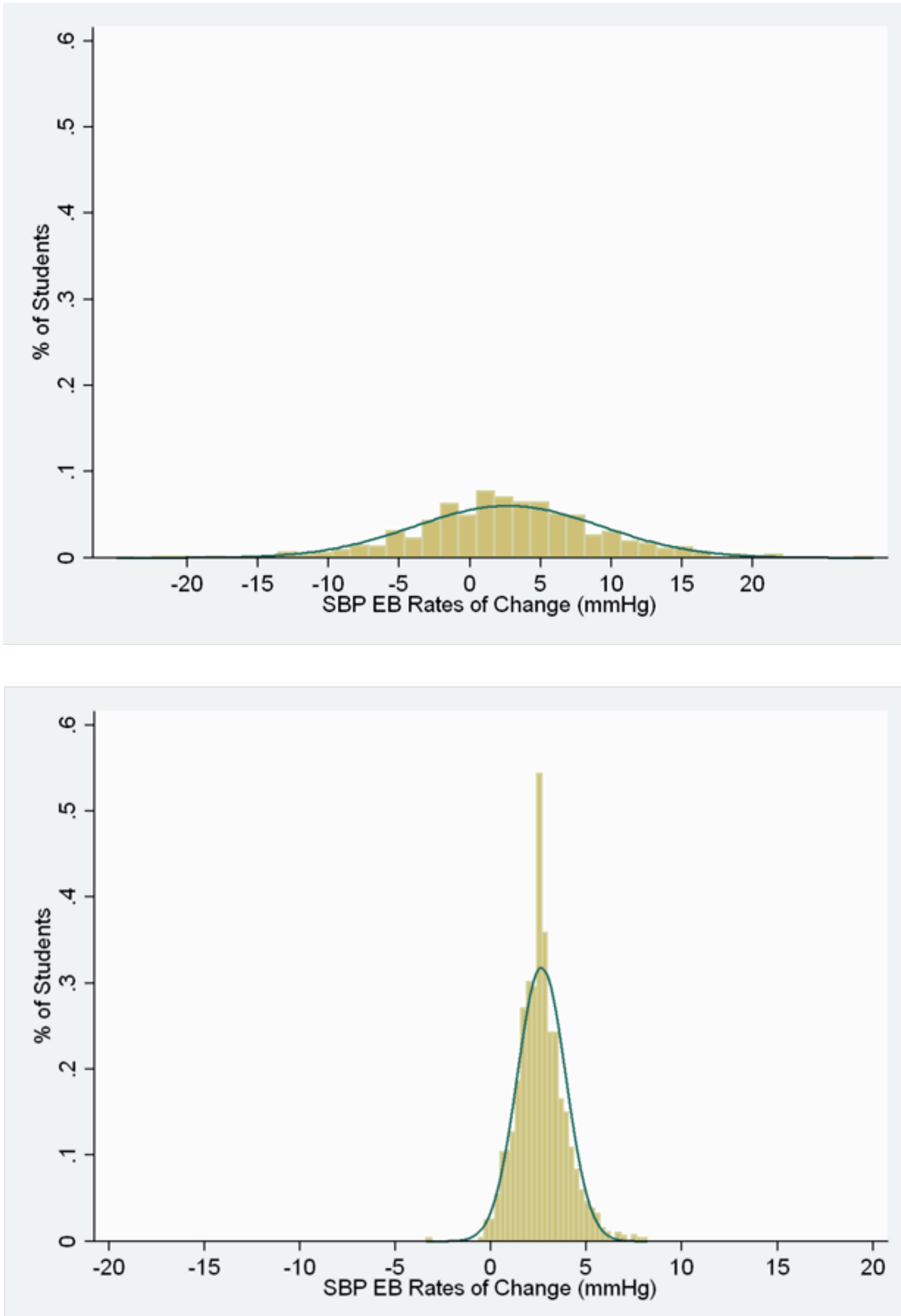

FIGURE 4.2. Distribution of “observed” (OLS) and “predicted” (EB) estimates of rates of change in systolic blood pressure

Abbreviations: OLS, ordinary least squares; EB, empirical Bayes.

The Empirical Bayes approach improves the precision of parameter estimates by treating the rest of the data, or the overall mean, as a "prior".(286) The SBP variance was reduced ("shrunk") toward the population average by multiplying blood pressure values by the "shrinkage factor" equal to the inverse of each of the 2 variances: that of an observed estimate for a particular individual and of the age-, sex-, and height-specific population average. From sex-specific individual growth models, I estimated between- and within-individual variance for SBP.

The variance in SBP was reduced ("shrunk") toward the population average as follows:

If BP_i is the individual-specific mean [$Var(BP_i) = \sigma_u^2 + \sigma^2 / n_i$] and

BP is the overall mean [$Var(BP) = \sigma_u^2 / j$], where

j is number of clusters, then

[$Var(SF * BP_i + (1 - SF) * BP) < Var(BP_i)$], where

SF is a "shrinkage factor": $SF = n_i\sigma^2_{between} /(n_i\sigma^2_{between} + \sigma^2_{within})$.

I estimated the "shrinkage factor" for boys and girls as follows:

Boys: SF = 53.62047/(53.62047+77.40179/605)= 0.99762

Girls: SF = 50.32747/(50.32747+42.56071/653)= 0.99871

I then multiplied SBP values by the factor equal to the sex-specific "shrinkage factor".

Analysis

To examine the longitudinal association between changes in physical activity and SBP in youth, and to assess whether this association is mediated by changes in adiposity, estimates of initial level and rate of decline in number of MVPA sessions per week from individual growth models were used as predictors of SBP in linear regression models.

First, to represent each student's pattern of number of MVPA sessions over time during early and late adolescence, estimates of initial level (i.e., intercept) and rate of change over time (i.e., slope) were derived from individual growth models for each student, for each of the two periods. Repeated assessments of MVPA sessions for each student were analyzed using individual growth modeling with student's age representing time. Age was "centered" on 12 years for the early adolescence models, and on 15 years for the late adolescence models to facilitate the interpretation of the intercept as an estimate of physical activity at age 12 or 15 years, rather than at age zero.(140) Month of data collection was used to adjust for seasonal variation in the number of MVPA sessions.(278)

Next, the estimates of each student's intercept and slope for the number of MVPA sessions per week were used as predictors of blood pressure at the end of early (mean age 15.2 years) and late adolescence (mean age 17.0 years).

I estimated the following six sex-specific models for each of the two study periods:

Model 1A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI

Model 2A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI + change in BMI + BMI interaction

Models 1B and 2B were as above except that waist circumference was used as a measure of adiposity. Models 1C and 2C were as above except that the sum of skinfold thickness was used as a measure of adiposity.

Model 1A included estimates of initial level and the rate of decline in the number of MVPA sessions per week; initial (baseline) levels of SBP; BMI; height, change in height, an interaction between initial height and change in height; age at the time of SBP measurement; and smoking (self-reported number of cigarettes smoked in the past week (preceding data collection) that was averaged over follow-up). To examine if these associations were mediated by changes in adiposity, Model 2A also included change in BMI during the period and an interaction between initial BMI and change in BMI. Height and change in height were used as crude proxy measures of the maturation process.(287) The interaction terms for height and BMI were added since height and weight may increase faster in adolescents with a higher initial height or BMI.(210) These two models were repeated for waist circumference (Models 1B and 2B) and skinfold thickness (Models 1C and 2C).

Objective 3

To assess whether weight misperception is associated with exposure to overweight/obese people at home or in school, I fitted two-level linear regression models to QCAHS Survey data to take the nested data structure into account (i.e., students within schools). Similar to the individual growth models described above, multi-level regression models allow us to estimate fixed effects at the student (parent BMI, gender) and school level (schoolmate BMI) as well as random effects to assess the extent to which misperception varied between schools.

Since deviation units of weight status misperception measure were nearly normally distributed (Figure 4.3), a measure of misperception was used as a continuous dependant variable in the analyses.

I estimated the following four models for each of the three age groups to assess the effects of parent and schoolmate BMI singularly and simultaneously, while controlling for the effect of gender:

Base Model:

Student-level: Misperception = $\beta_{0j} + \beta_{1j}\,(\text{Gender}_{ij}) + \varepsilon_{ij}$

School-level: $\beta_{0j} = \gamma_{00} + \zeta_{0j}$

$\beta_{1j} = \gamma_{10}$

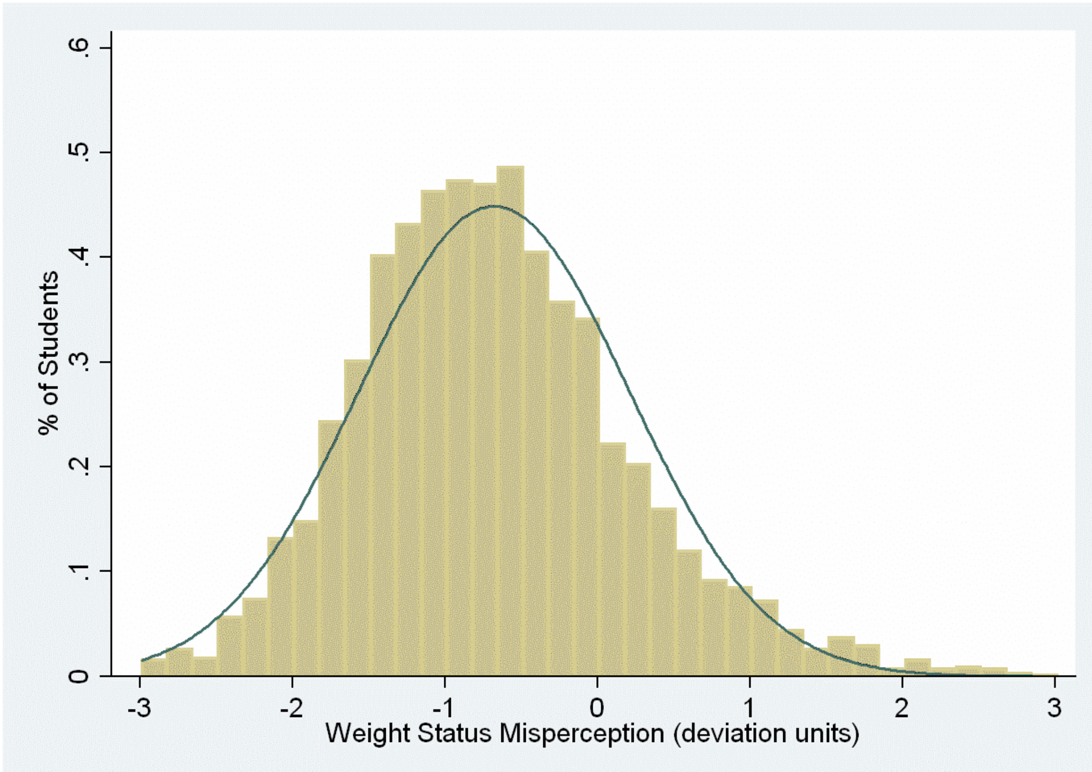

FIGURE 4.3. Distribution of weight status misperception

Model 1:

Student-level: Misperception = $\beta_{0j} + \beta_{1j}\,(\text{Gender}_{ij}) + \beta_{2j}\,(\text{Parent BMI}_{ij}) + \varepsilon_{ij}$

School-level: $\beta_{0j} = \gamma_{00} + \zeta_{0j}$

$\beta_{1j} = \gamma_{10}$

$\beta_{2j} = \gamma_{20}$

Model 2:

Student-level: Misperception = $\beta_{0j} + \beta_{1j}\,(\text{Gender}_{ij}) + \varepsilon_{ij}$

School-level: $\beta_{0j} = \gamma_{00} + \gamma_{01}\,(\text{Schoolmate BMI}_{j}) + \zeta_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}\,(\text{Schoolmate BMI}_{j})$

Model 3:

Student-level: Misperception = $\beta_{0j} + \beta_{1j}\,(\text{Gender}_{ij}) + \beta_{2j}\,(\text{Parent BMI}_{ij}) + \varepsilon_{ij}$

School-level: $\beta_{0j} = \gamma_{00} + \gamma_{01}\,(\text{Schoolmate BMI}_{j}) + \zeta_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}\,(\text{Schoolmate BMI}_{j})$

$\beta_{2j} = \gamma_{20}$

The base model included gender and the random intercept to assess the effect of gender on misperception of weight status, accounting for the clustering by school. To assess whether exposure to overweight at home and in school were associated with misperception of weight status, parent and schoolmate BMI were added to the base model singularly and simultaneously (parent BMI in Model 1; schoolmate BMI in Model 2; parent and schoolmate BMI in Model 3). These models were tested for each age group separately as the school-based sampling procedure, where 9, 13 and 16 year olds were derived from separate samples of schools, precluded using the entire dataset with age as a covariate due to multicollinearity between school and age variables. For all models, parent and schoolmate BMI were grand-mean centered to facilitate interpretation of the results. Centering a variable about its grand-mean yields an intercept that is interpreted as the estimate at the mean of a given variable, rather than at zero. Centering does not change the values or the significance levels of the estimated coefficients.(288)

Objective 4

To test the hypothesis that youth who underestimate their weight status engage in fewer physical activity sessions per week than those who do not underestimate their weight status, I fitted sex-specific Poisson regression models to QCAHS Survey data. In order to take the loss of precision resulting from the stratified, cluster sampling design of the QCAHS Survey into account, I used design effects that were defined as a ratio of the variance under current study design to the variance that would have been obtained under simple random sampling.(272)

I estimated the following sex-specific model:

Physical Activity = misperception + age + parent BMI + parental education + household income

To examine if misperception of weight status among youth is associated with the level of participation in physical activity, the model included weight status misperception; student's age (age 9 years as a reference category); parental BMI (self- report of height and weight was provided by the parent completing the questionnaire); parental education (less than high school education based on self-report by the parent completing the questionnaire); and household annual income (less than $20,000 based on self-report by the parent completing the questionnaire).

Ethics

The NDIT Study was approved by the Institutional Review Boards at the Direction de santé publique de Montréal -Centre, McGill University and the Centre de recherche du Centre hospitalier de l'Université de Montréal (CRCHUM). All students provided assent and their parents/guardians provided signed informed consent. To ensure that data anonymity and confidentiality are maintained, students' names were replaced with identification numbers and the NDIT Study data set containing only identification numbers to link individual student's data from different waves was used to carry out the longitudinal data analyses.

The QCAHS study procedures were approved by the ethics committees of the Direction Santé Québec of the Institut de la Statistique du Québec, the Ministère de l'Éducation du Québec, and Ste-Justine Hospital. The use of provincial lists of school-aged youth for the sampling frame was approved by the Commission d'accès à l'information du Québec. All students and their parents/guardians provided signed informed consent. Students' names were replaced with unique identification numbers and the master list matching student names and identification numbers was destroyed after the data collection. The QCAHS Survey data set containing only identification numbers was used to carry out the data analyses.

Chapter 5: Manuscript I

Prevention of excess weight gain in youth may help prevent higher SBP during childhood and adolescence. Two recent longitudinal cohort studies reported that sex differences in SBP increases with age were already evident in adolescence, highlighting the establishment of differential risk early in life.(131, 135) It is currently not well understood when or how sex differences in SBP appear during the lifecourse. In this first manuscript, we assessed whether sex differences in SBP increases with age are related to changes in height and adiposity indicators during adolescence. This study adds to the limited longitudinal evidence on blood pressure increases with age during childhood and adolescence. It is one of the few longitudinal studies that used analytical techniques that adjust for intra-individual variability in BP and that used several indicators of adiposity including BMI, waist circumference, and skinfold thickness, to estimate the effect of changes in weight or body fat on changes in SBP during adolescence.

TITLE: The impact of changes in anthropometric characteristics on blood pressure during adolescence

SHORT TITLE: Growth and blood pressure changes in adolescence

AUTHORS: Katerina Maximova, Jennifer O'Loughlin, Gilles Paradis, James A. Hanley, John Lynch

This manuscript is under review in the journal *Epidemiology*.

ABSTRACT

Background: Studies suggest that sex differences in blood pressure are established early in life. It is unclear whether sex differences in blood pressure increases during adolescence may be due to differences in gains in anthropometric characteristics.

Methods: Using sex-specific individual growth models, we assessed the effect of height, BMI, waist circumference, and triceps and subscapular skinfold thickness on changes in systolic blood pressure in a cohort of 1293 adolescents in Montréal, Canada. Blood pressure and anthropometry were assessed biannually (1999/2000, 2002, 2004) at mean ages 12.8, 15.2, and 17.0 years.

Results: On average, systolic blood pressure (SBP) increased by 11.1 mmHg in boys and 3.2 mmHg in girls over five years. Changes in height explained half of the overall increase in SBP in boys and virtually all increases in SBP in girls. No significant sex differences were observed in the association of changes in BMI, waist circumference, and triceps and subscapular skinfold thickness with SBP change over five years. An increase in one BMI unit, one cm waist circumference, or one mm triceps and subscapular skinfold thickness was associated 0.7 mmHg, 0.24 mmHg, 0.3 and 0.4 mmHg SBP increase.

Conclusion: While sex differences in mean SBP changes during adolescence were largely attributable to differences in gains in height, the effect of gaining weight or body fat on SBP change was similar in boys and girls.

KEYWORDS: obesity, adolescents, blood pressure, epidemiology, sex.

BACKGROUND

Elevated blood pressure is the leading cause of the global burden of cardiovascular disease (CVD).(6) Before menopause women have lower blood pressure levels than men of the same age.(101, 132) The incidence of hypertension is also higher in men than in women.(133) Although sex differences in blood pressure levels may be associated with higher CVD morbidity and mortality among men,(3) it is not well understood when or how the sex differences in blood pressure appear in the lifecourse.(134) Blood pressure increases with age during childhood and adolescence.(125) Recent evidence suggests that sex differences in the patterns of increases in systolic blood pressure (SBP) with age,(131, 135) and in the prevalence of high SBP(136) are already evident in adolescence.

The blood pressure increases with age are most pronounced during adolescence,(53) and may be related to the rapid increases in height, weight and body fat, associated with pubertal growth and physiological maturation (Figure 5.1).(122) Although the mechanisms responsible for blood pressure development in youth are currently not well understood,(68, 69) it is believed that obesity or excess weight promotes higher blood pressure through an increase in the sympathetic nervous activity, insulin resistance and arterial stiffness – all of which increase cardiac output and systemic vascular resistance.(70, 71) Weight loss improves insulin sensitivity and sympathetic nervous activity, and decreases cardiac output and systemic vascular resistance,(74-76) promoting restoration of normal blood pressure levels in obese youth.(68)

It remains unclear whether sex differences in the patterns of SBP increases with age during adolescence may be due to differences between boys and girls in gains in body size, adiposity, hormones, or some other factors.(134) The relationship between blood pressure increases with age and contemporaneous changes in height, weight and body fat on the burden of hypertension has important clinical and public health implications,(6) particularly in the context of the current childhood obesity epidemic.(36, 37) However, longitudinal cohort studies in this domain have been limited to exploring the patterns of blood pressure changes with age without considering the effect of changes in height, weight or other anthropometric characteristics. The objective of this study was to assess the sex-specific impact of changes in anthropometric characteristics such as height, BMI, waist circumference, and triceps and subscapular skinfold thickness, on SBP increases over five years in a cohort of adolescents.

METHODS

Study population

The Natural History of Nicotine Dependence in Teens (NDIT) Study is an ongoing prospective cohort of 1293 grade 7 students aged 12-13 years at baseline, recruited in Fall 1999 in a convenience sample of 10 Montréal secondary schools.(289) Schools were selected to include a mix of French and English schools, schools located in urban, suburban, and rural areas, and in high, medium and low socioeconomic neighbourhoods. All students provided assent and their parents/guardians provided signed informed consent. The Institutional Review

Boards at McGill University and Centre de recherche de Centre hospitalier de l'Université de Montréal approved the study protocol.

During the first five years of follow-up, SBP and anthropometry were measured three times (Fall 1999/Winter 2000, Spring 2002, and Spring 2004).(112) A total of 1192 students in 1999, 953 in 2002, and 799 in 2004 had SBP measurements and were available for analysis. The mean number of repeated blood pressure measurements available per student was 2.5 (718 (60.2 percent) students had blood pressure measured on all three occasions; 250 (21.0 percent) on two occasions; 290 (24.3 percent) on one occasion). Students were, on average, 12.8 years old in 1999, 15.2 in 2002 and 17.0 in 2004.

Measures

Blood pressure was assessed in the sitting position, on the right arm after voiding and a five-minute rest period with an automated oscillometric device (Dinamap XL, model CR9340, Critikon Co.) by technicians trained and certified according to a standardized protocol.(273) Oscillometric devices were calibrated against a mercury sphygmomanometer before each data collection period. A minimum of three blood pressure readings were recorded for each student at one-minute intervals. If the difference between the second and third readings was greater than 20 mmHg and 10 mmHg for systolic and diastolic blood pressure respectively, forth and fifth readings were taken. To reduce blood pressure reactivity/habituation (i.e., "white coat" effect), the first reading was not considered.(114) The mean value of the two readings with the least difference was calculated from the remaining readings.

Anthropometric measurements were collected with students dressed in light clothing without shoes using a stadiometer (model 214 Road Rod, Seca Corp.) for height, a scale (floor model 761, Seca Corp.) for weight, Lange-type Baseline Skinfold calipers (AMG Medical Inc.) for skinfold thickness, and a standard tape measure just above the uppermost border of the right ilium at the end of normal expiration for waist circumference. Measurements were recorded to the nearest 0.1 cm for height, 0.2 kg for weight, 0.1 cm for waist circumference, and 0.5 mm for skinfold thickness. Two measurements were obtained for each participant. A third measurement was taken if the difference between the first two measurements was greater than 0.5 cm for height, 0.2 kg for weight, 0.5 cm for waist circumference, and 1 mm for skinfold thickness. All anthropometric measurements were repeated systematically on every tenth student to assess inter-rater reliability (ICC=0.99 for height and weight, 0.98 for waist circumference, and 0.95 for triceps and 0.96 for subscapular skinfold thickness). For all anthropometric measurements, the mean value of two measurements with the least difference was calculated. BMI was computed as weight/height^2 (kg/m^2).

Analysis

Sex-specific change patterns in mean blood pressure and anthropometric characteristics (height, weight, BMI, waist circumference, and triceps and subscapular skinfold thickness) over five years were assessed using the Lowess curve smoothing technique, based on a series of locally weighted means.(290) The repeated SBP measurements in 1999/2000, 2002, and 2004 were analyzed using sex-specific individual growth modeling. This analytic approach assumes that each student has a different linear change/increase in SBP with age. It estimates the average change over time (fixed effect of time) and the variation in SBP initial levels and rates of change that vary randomly between students (variance components). It can also account for time-varying predictors of the linear change in SBP, such as height and other anthropometric characteristics. Student's age represented time and height was included in the models as a crude proxy measure of the maturation process.

Model 1 included the effect of time and two sources of variation – between- and within-student variation. Variance between students was further decomposed into variance in initial levels and in rates of SBP change. To assess whether changes in SBP over five years and variation in change patterns between students could be attributed to changes in anthropometric characteristics, Model 2 included the time-varying effect of height. The time-varying effect of other anthropometric characteristics were then added to Model 2 separately (BMI in Model 3, waist circumference in Model 4, and triceps and subscapular skinfold thickness in Models 5 and 6). The effect of BMI, waist circumference, and measures of skinfold thickness could not be tested simultaneously due to multicollinearity. All associations were adjusted for physical activity (self-reported number of physical activity sessions ≥5 minutes in the past week (preceding data collection) that was averaged over follow-up) and smoking (self-reported number of cigarettes smoked in the past week that was averaged over follow-up). In order to formally test sex differences in these associations, we estimated models with interaction terms for sex and age, height, BMI, waist circumference, triceps and subscapular skinfold thickness.

For all models, age and anthropometric characteristics were "centered" on their respective minimum values (closest integer) to facilitate the interpretation of the results (age was "centered" on 12 years, height on 130 cm, BMI on 13 kg/m^2, triceps and subscapular skinfold thickness on 4 mm and 3 mm respectively, and waist circumference on 45 cm). "Centering" a variable about its minimum value yields an intercept that is interpreted as an estimate of SBP at that value (e.g., baseline values refer to SBP at age 12), rather than at zero.

RESULTS

Sample characteristics of students at baseline when they were 12-13 years old, on average, are presented in Table 5.1. Increases in mean SBP over five years were substantial in boys and modest in girls (Figures 5.2.1 and 5.2.2). On average, SBP increased by 11.1 mmHg (103.5 to 114.6 mmHg) in boys and 3.2 mmHg (103.1 to 106.3 mmHg) in girls. Diastolic blood pressure increased by 4.0 mmHg (55.3 to 59.3 mmHg) in boys and 2.6 mm Hg (56.0 to 58.6 mmHg) in girls. Boys underwent substantial growth in height, which increased by 21.3 cm (154.0 to 175.3 cm). Height increased by 8.9 cm in girls, with the most substantial increases occurring before the age of 15 (154.0 to 162.9 cm), after which growth in height slowed down. BMI increased by three units (kg/m^2) in both boys and girls. Increases in waist circumference were greater in boys than girls (8.4 vs. 7.0 cm). Girls experienced greater increases in triceps and subscapular skinfold thickness over five years than boys (7.9 and 6.7 mm vs. 0.5 and 3.9 mm).

Among boys, the average SBP level at age 12 years was 103.6 mmHg and SBP increased on average by 2.2 mmHg with each year of age (Model 1, Table 5.2), and thus 11 mmHg over five years (illustrated in Figure 5.2.1). When individual changes in height over five years were taken into account (Model 2), the rate of SBP change with each year of age was reduced by half (1.0 mmHg). SBP increased by 0.25 mmHg with each cm increase in height (Model 2). Since boys' height increased by 21 cm over five years, the increase in SBP of 0.25 mmHg with each cm of height corresponds to SBP increase of 5.3 mmHg over five years. Hence, half of the overall increase in SBP (11.1 mmHg over five years) was explained by changes in boys' height. When individual changes in other anthropometric characteristics over five years were taken into account (Models 3-6), an increase over time in one BMI unit, one cm waist circumference, or one mm triceps and subscapular skinfold thickness was associated 0.7 mmHg (Model 3), 0.24 mmHg (Model 4), 0.3 and 0.4 mmHg (Models 5 and 6) SBP increase.

There was no clear linear pattern in SBP changes over five years in girls. The parameter estimates of the rate of change with each year of age reflected the modest changes in SBP in girls (observed in Figure 5.2.1). Although the average SBP level at age 12 years in girls was similar to that of boys (104.1 mmHg), SBP increased, on average, by 0.3 mmHg with each year of age (Model 1, Table 5.2).

The estimate for the rate of change in SBP with age decreased to zero (Model 2) and was no longer statistically significant once changes in height were accounted for, suggesting that virtually all increases in SBP were explained by changes in girls' height. The effect of height was slightly lower than that observed in boys; SBP increased by 0.2 mmHg with each cm increase in height (Model 2).

The effect of changes in other anthropometric characteristics on changes in SBP over five years was of similar magnitude to that observed in boys. An increase over time in one BMI unit, one mm of triceps and subscapular skinfold thickness, or one cm of waist circumference was associated with 0.7 mmHg (Model 3), 0.26 mmHg (Model 4), or 0.3 and 0.4 mmHg (Models 5 and 6) SBP increase. Since there were no sex differences in age-related mean change patterns in diastolic blood pressure, we did not explore the effect of changes in anthropometric characteristics on individual changes in diastolic blood pressure over time. No significant sex differences were observed in the association of SBP with height, BMI, waist circumference, and triceps and subscapular skinfold thickness (Table 5.2).

There was substantial variation between boys in their initial levels of SBP (SD=7.5), indicating a substantial unexplained heterogeneity in boys' SBP levels at age 12 years (Model 1, Table 5.2). However, there was little significant heterogeneity in boys' rates of SBP change (SD=0.8, Model 1). There was also substantial unexplained heterogeneity in girls' SBP levels at age 12 years and little heterogeneity in their rates of change (SD=6.9 and SD=0.6, Model 1, Table

5.2). Variation in SBP levels at age 12 between boys was partly due to their differences in height and other anthropometric characteristics; it was reduced with the inclusion of height and BMI (SD=6.7, Model 3) and of height and waist circumference (SD=6.8, Model 4, Table 5.2). Similar to boys, the variation in initial levels was reduced most substantially with the inclusion of height and BMI (SD=6.4, Model 3), and of height and waist circumference (SD=6.5, Model 4).

The within-student variance, which reflects the extent to which each student's observed SBP values on each of the three measurement occasions deviate from his or her own estimated linear change pattern, was also substantial (SD=7.3 in boys and SD=6.4 in girls), representing nearly half of the total variation in SBP. This component of the total variance represents the extent of measurement error ("noise") in estimated linear change patterns. Only a small proportion of the within-student variance was systematically associated with changes in anthropometric characteristics.

DISCUSSION

We examined SBP changes over five years in a cohort of adolescents in relation to changes in anthropometric characteristics. Although boys and girls had similar mean SBP levels at age 12 years, SBP increased relatively rapidly with age in boys, but only modestly in girls. These sex differences in mean SBP progression are consistent with previous studies, which show that SBP increases were greater in girls until age 12 years. However, SBP increases level off and decline in late teens in girls, while BP continues to increase at a steeper rate for boys until age 18 years. (126, 131) In this study, steep increases in SBP in boys over five years were due in large part to changes in height, with half of the increase in SBP attributable to contemporaneous changes in boys' height during this period. Although increases in girls' height and SBP were modest, the effect of changes in girls' height on SBP change was of similar magnitude to boys and explained virtually all SBP increases in girls.

Increases in mean BMI were similar in both boys and girls over five years. However, triceps and subscapular skinfold thickness (a crude measure of subcutaneous body fat) increased substantially in girls but not in boys, while increases in waist circumference (a crude measure of abdominal fat) were slightly higher in boys than girls. These trends in anthropometric characteristics during this age period are consistent with those recently reported in the literature.(135, 229) While previous studies highlighted sex differences in mean change patterns in blood pressure and anthropometric characteristics during adolescence,(135) they did not directly attribute changes in blood pressure to contemporaneous changes in anthropometric characteristics. Results of our study show that despite differences in mean change patterns in SBP and anthropometric characteristics between boys and girls, the magnitude of the effect of changes in height, BMI, waist circumference, and skinfold thickness over time on SBP changes was similar in boys and girls. Thus, regardless of sex differences in mean trends in blood pressure and adiposity indicators, the effect of gaining weight or body fat on blood pressure change was the same in both sexes.

While both abdominal and upper-body fat are strongly related to CVD risk factors in youth,(234, 291) abdominal adiposity is more related to blood pressure in youth than subcutaneous adiposity.(223, 232) Waist circumference, in particular, has been recently advocated as a better adiposity indicator and a more important predictor of blood pressure and cardiovascular risk in youth than BMI.(243, 244, 292) However, BMI, waist circumference, and subscapular skinfold thickness had similar effects on changes in SBP in our study. Although the parameter estimates differed since these variables were measured on different scales, the estimates of effect size were similar. Partial Eta squared, a standardized measure of the magnitude of the effect in regression analysis, was 0.6 and 0.7 for BMI in boys and girls, 0.5 and 0.6 for waist circumference in boys and girls, and 0.5 for subscapular skinfold thickness in both boys and girls. Our study showed no superiority of waist circumference or another anthropometric characteristic in predicting blood pressure changes in adolescents. Lastly, although waist circumference and skinfold thickness were recently shown to have a weaker association with SBP in girls than in boys,(131) our study did not find sex differences in the association of SBP with each of the anthropometric characteristics.

We found substantial between-person variation in blood pressure at age 12, but little variation in rates of change (slopes) in adolescents. These findings indicate that while blood pressure levels may vary widely between adolescents at age 12, the course of blood pressure changes/increases after age 12 does not and each adolescent may already follow his/her own change trajectory. Although within-person variability was high in our study, this finding is consistent with the study by Shea et al (1998) and several cross-sectional studies that reported on within-person variability in youth's blood pressure using mixed regression models.(107, 293)

The key strength of this study was the use of individual growth modeling. This approach has the advantage over analytic methods that rely on population average measures (e.g., generalized estimating equations (GEE)) because in addition to providing an estimate of an average change pattern, it provides an estimate of between-student variation in these patterns.(140) Although blood pressure change patterns vary between individuals,(138) only a small number of longitudinal studies taken into account this variability in blood pressure.(131, 135, 138) Using individual growth modeling of six repeated measurements of SBP in pre-pubertal children, Shea et al (1998) reported substantial variability in individual patterns of blood pressure changes between children, concluding that models that assume no individual variation in blood pressure change patterns are not well suited for understanding blood pressure progression in youth.(138) Other strengths of our study include the longitudinal follow-up of this cohort of adolescents, repeated blood pressure measurements over five years and multiple readings of blood pressure on each data collection occasion.

Limitations of our study include the use of a convenience sample. However, while this may have implications for a prevalence or incidence study of elevated blood pressure, it should not affect the magnitude of the relation between longitudinal changes in blood pressure and its predictors. Other major studies of blood pressure and cardiovascular health in youth were also based on convenience samples (e.g., Bogalusa Heart Study). Since blood pressure levels in different populations reported in other studies are not directly comparable as they depend on blood pressure measurement methods, the number of readings, time of day, etc,(79) the external validity of a convenience sample is better assessed using behavioural characteristics. Previous studies using this dataset showed that NDIT Study participants present health-related behaviours similar to those of a representative sample of Québec youth.(294)

In this study, BMI, waist circumference, and triceps and subscapular skinfold thickness were considered to be crude indicators of adiposity in youth, representing overall, abdominal and upper-body subcutaneous fat, respectively. Changes in body composition in youth over time are poorly reflected by changes in BMI,(223, 228) since, unlike in adults, increases in BMI in children age 8 to 18 years are primarily related to increases in lean (fat free) mass rather than fat mass.(229, 230) In the longitudinal study Project HeartBeat!, SBP was independently associated with fat mass and fat free mass.(131) However, the correlation between BMI and fat mass was r=0.9, indicating that BMI is closely associated with fat mass.(211) While waist circumference and measures of skinfold thickness may offer an improvement over BMI in assessing changes in body composition in youth over time, they still may not reflect important changes in fat mass and fat free mass components that occur during adolescence. Height was included in the models as a crude proxy measure of the maturation process.

The growth spurt in height begins earlier in girls than boys since pubertal maturation begins and ends earlier in girls than boys. This aspect of height would not be captured in the BMI values because they are intended to measure a different underlying construct – weight adjusted for height.(295)

Since sex and age are the main determinants of SBP levels in youth,(34) we conducted sex-specific analyses to minimize the possibility of residual confounding by sex when investigating SBP increases with age (exogenous variable).(296) The majority of adolescents in the NDIT Study cohort were aged 12-13 years at baseline but the age distribution ranged from 11 to 16 years. We centered age on 12 years in individual growth models in order to reflect changes in blood pressure from age 12 to 17 years. However, adjusting the association between SBP and age for intermediary variables such as height and BMI, may not remove confounding effects of these factors since their association with SBP may be confounded by unobserved variables such as diet and physical activity (Figure 5.1).(297) The growth spurt in height begins earlier in girls than boys since pubertal maturation begins and ends earlier in girls than boys; almost all girls complete pubertal maturation by age 15 years.(131, 298)

Difficulties in measuring blood pressure in youth may lead to a misclassification of a student's "true" blood pressure level.(102, 299) However, automated measurement devices, such as the Dinamap used in NDIT Study, have several key advantages. Compared with mercury sphygmomanometer methods, they requires relatively little training; they avoid observer bias due to digit preference or knowledge of prior readings; they are relatively easy to use with small children because there is no need for auscultation. The SBP readings obtained with a Dinamap device correlate well with intra-arterial readings obtained by direct auscultatory method,(103, 110) and have been shown to provide accurate readings in children.(111) A validation study in 52 youth 8-16 years old with a BMI range of 15-45 kg/m^2 found no systematic differences between the Dinamaps used in NDIT Study and mercury sphygmomanometers.(32) Reliability of blood pressure measurements can be improved by increasing the number of readings on each measurement occasion and in NDIT Study, each child had a minimum of three and up to five readings. While automated devices can still lead to bias, it is likely to be of the same magnitude on different measurement occasions. Individual growth modeling takes into account within-student variability inherent in blood pressure (i.e., measurement error/"noise"). Within-person variability has also been reported to be substantially lower (approximately half) in older children (13-18 years old) than younger children (8-12 years old).(293)

Modeling longitudinal changes with three data points required an assumption that blood pressure increases linearly with age and precluded inclusion of a quadratic term. Although Shea and colleagues suggest that quadratic form may be more appropriate for modeling blood pressure change in children, inclusion of a quadratic term may have been necessary in their study based on pre-pubertal children aged 5 to 8 years old to reflect the sharp increases in blood pressure as children were entering puberty during the follow-up. However, adolescents in NDIT Study cohort were, on average, 12-13 years old at baseline, and had already entered puberty. No measure of pubertal maturation was available in NDIT Study. Changes in height were used as a crude proxy for the maturation process in our study.(287) The effect of changes in height on SBP remained stable across models that included BMI, waist circumference, and skinfold thickness; and the correlation between height and other anthropometric characteristics in each model was low (Appendix). Changes in height then explained a proportion of variance uncorrelated with the variance explained by other anthropometric characteristics.

The relationship between SBP increases with age and contemporaneous changes in weight and body fat during adolescence has important clinical and public health implications for the burden of hypertension, particularly in the context of the current childhood obesity epidemic. The evidence is only beginning to emerge on sex differences in the patterns of SBP increases with age and their relationship with contemporaneous changes in anthropometric characteristics. Results of this study suggest that while sex differences in mean blood pressure changes during adolescence were largely attributable to differences in individual gains in height between boys and girls, the effect of gaining weight or body fat on blood pressure change was similar in boys and girls.

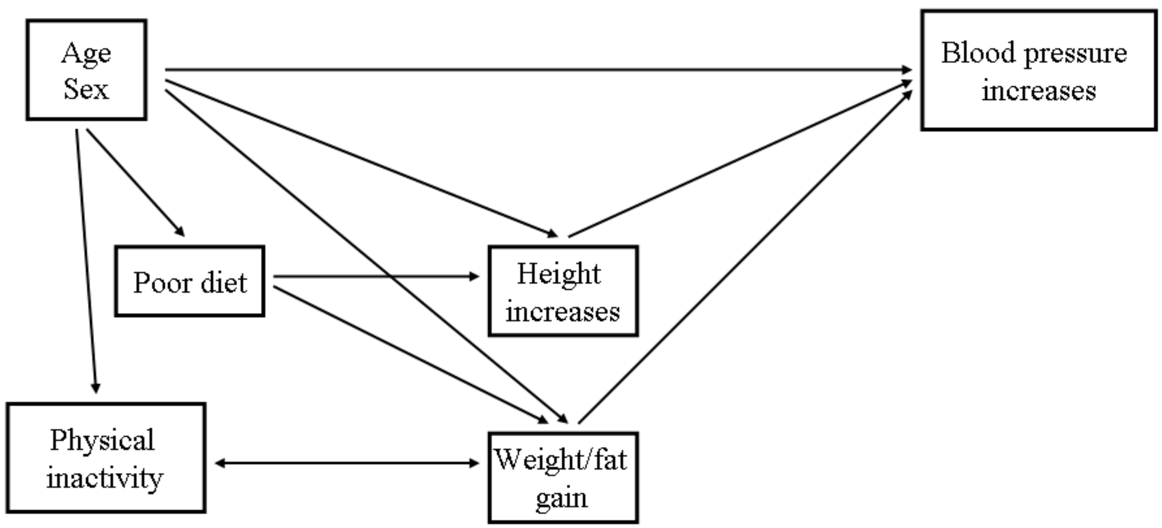

FIGURE 5.1. Relationships between major risk factors and blood pressure in youth

TABLE 5.1. Sample characteristics of adolescent boys and girls at baseline, NDIT Study, Montréal, Canada, 1999/2000-2004

	Boys (n=614)		Girls (n=653)	
	Mean	SD	Mean	SD
Age, years	12.8	(.6)	12.7	(.6)
Systolic blood pressure, mm Hg	105.9	(10.9)	104.7	(9.4)
Diastolic blood pressure, mm Hg	56.2	(6.3)	56.9	(6.4)
Height, cm	156.6	(8.8)	155.8	(6.7)
Weight, kg	49.7	(12.)	48.9	(11.5)
BMI, kg/m^2	20.1	(3.8)	20.0	(3.9)
Waist circumference, cm	72.6	(10.3)	69.8	(9.8)
Triceps skinfold thickness, mm	13.3	(6.4)	14.9	(5.6)
Subscapular skinfold thickness, mm	9.6	(5.9)	10.8	(5.3)
Resting heart rate, bpm	83.8	(12.7)	86.1	(11.5)

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; SD, standard deviation; BMI, body mass index.

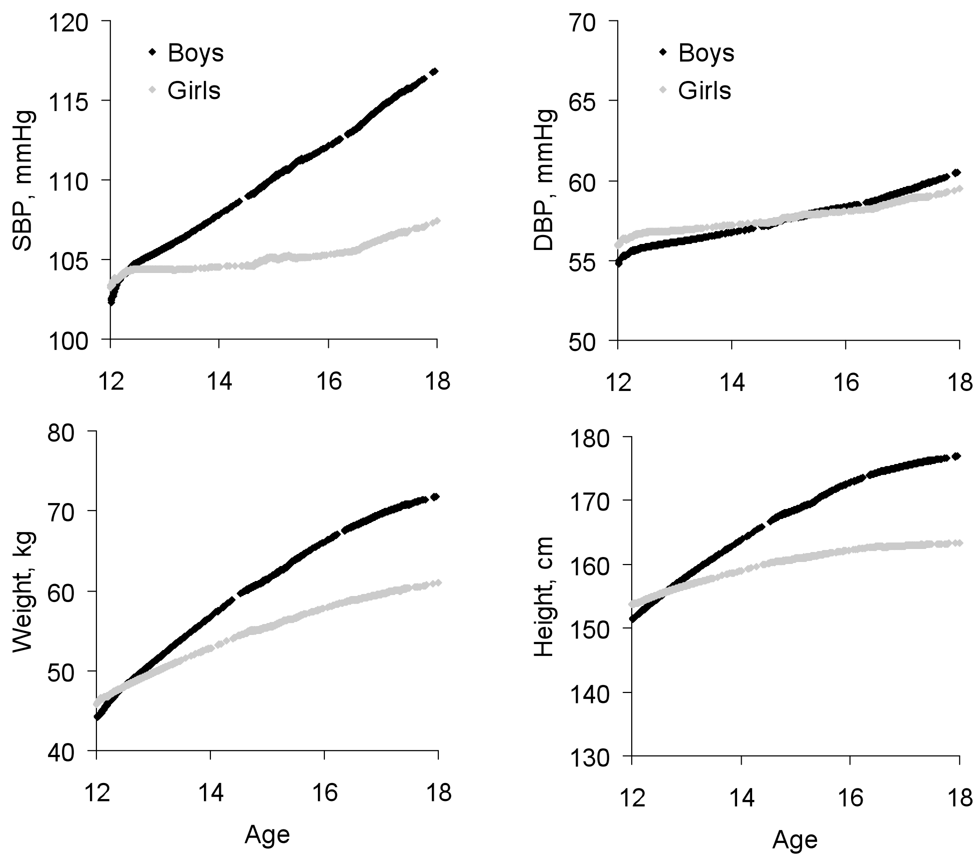

FIGURE 5.2.1. Changes in systolic and diastolic blood pressure, height and weight in boys and girls from age 12 to 18 years, NDIT Study, Montréal, Canada, 1999/2000-2004

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Key to figure: Each plot represents sex- and age-specific means of systolic and diastolic blood pressure, height, weight, estimated by the Lowess curve smoothing method.

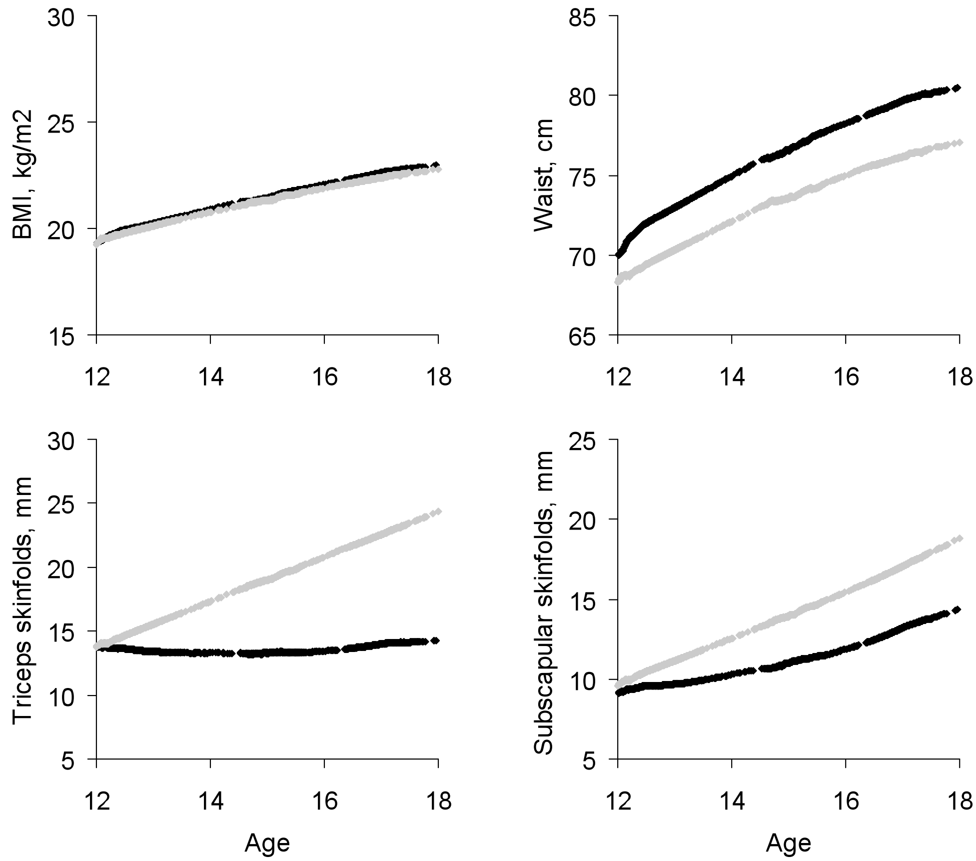

FIGURE 5.2.2. Changes in BMI, waist circumference, triceps and subscapular skinfold thickness in boys and girls from age 12 to 18 years, NDIT Study, Montréal, Canada, 1999/2000-2004

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; BMI, body mass index (kg/m^2).

Key to figire: Each plot represents sex- and age-specific means of BMI, waist circumference, and triceps and subscapular skinfold thickness, estimated by the Lowess curve smoothing method.

TABLE 5.2. Estimates of initial level[a] and rate of change[a] in systolic blood pressure (mmHg) over five years in boys and girls, NDIT Study, Montréal, Canada, 1999/2000-2004

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Estimate[b]	**SE**	**Estimate[b]**	**SE**	**Estimate[b]**	**SE**	**Estimate[b]**	**SE**	**Estimate[b]**	**SE**	**Estimate[b]**	**SE**
Fixed effects												
Initial level												
Boy	103.6	(.47)	97.6	(1.04)	93.6	(1.11)	94.8	(1.14)	95.2	(1.06)	92.9	(1.21)
Girl	104.1	(.40)	99.1	(1.17)	96.1	(1.17)	97.2	(1.18)	97.5	(1.16)	95.6	(1.21)
Rate of change (age)												
Boy	2.2	(.12)	1.0	(.22)	0.7	(.22)	0.9	(.22)	0.6	(.22)	0.9	(.22)
Girl	0.3	(.10)	0.0[ns]	(.13)	-0.3	(.13)	-0.5[ns]	(.14)	-0.5	(.14)	-0.3	(.13)
Height												
Boy			0.2	(.04)	0.2	(.04)	0.3	(.04)	0.3	(.04)	0.2	(.04)
Girl			0.2	(.04)	0.1	(.04)	0.2	(.04)	0.2	(.04)	0.1	(.04)
BMI												
Boy					0.7	(.09)						
Girl					0.7	(.08)						
Waist circumference												
Boy							0.3	(.05)				
Girl							0.3	(.04)				
Triceps skinfolds												
Boy									0.4	(.05)		
Girl									0.4	(.05)		
Subscapular												

skinfolds												
Boy											0.2	(.03)
Girl											0.3	(.03)
<u>Sex interactions</u>[c]												
Sex x Initial level	0.6	(.54)	2.0^{ns}	(1.44)	3.1	(1.47)	3.3	(1.55)	2.7^{ns}	(1.5)	2.7^{ns}	(1.44)
Sex x Age	-1.9	(.20)	-0.9	(.27)	-0.9	(.26)	-1.0	(.26)	-1.3	(.27)	-1.1	(.27)
Sex x Height			-0.1^{ns}	(.05)	-0.1	(.05)	-0.1	(.06)	-0.1	(.05)	-0.1	(.05)
Sex x BMI					0.0^{ns}	(.11)						
Sex x Waist circumference							0.0^{ns}	(.04)				
Sex x Triceps skinfolds									0.1^{ns}	(.06)		
Sex x Subscapular skinfolds											0.0^{ns}	(.07)
Variance components												
<u>Between-student</u>												
In initial level												
Boy	7.5	(.36)	7.1	(.36)	6.7	(.35)	7.0	(.36)	6.9	(.35)	6.8	(.36)
Girl	6.9	(.30)	6.8	(.30)	6.5	(.29)	6.7	(.29)	6.6	(.29)	6.5	(.29)
In rate of change (age)												
Boy	0.8	(.21)	0.9	(.18)	0.9	(.17)	0.9	(.17)	1.0	(.17)	0.9	(.17)
Girl	0.6	(.20)	0.6	(.19)	0.6	(.20)	0.7	(.17)	0.7	(.17)	0.6	(.19)

Within-student													
	Boy	7.3	(.20)	7.2	(.20)	7.1	(.19)	7.1	(.20)	7.1	(.20)	7.2	(.20)
	Girl	6.4	(.17)	6.4	(.17)	6.3	(.17)	6.2	(.17)	6.2	(.17)	6.3	(.17)

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; SE, standard error; ns, not significant.
[a] Initial level (β_{0i}) and rate of change (β_{1i}) in systolic blood pressure (mmHg), adjusted for physical activity and smoking, from the individual growth models (see Methods).
[b] All estimates are significant ($p<0.05$) except for those marked not significant (ns).
[c] Estimates of interaction terms of sex with each of the anthropometric characteristics from individual growth models.

Model 1: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$
Model 2: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$
Model 3: $SBP_{ij} = \gamma_{00} + \gamma_{10}(Age_{ij}) + \beta_{20}(Height_{ij}) + \beta_{30}(BMI_{ij}) + \zeta_{0i} + \zeta_{1i}(Age_{ij}) + \varepsilon_{ij}$
Models 4-6 are same as Model 3 except that waist circumference, triceps and subscapular skinfold thickness, respectively, were used in place of BMI.

SBP_{ij} – blood pressure value for the i^{th} student at j^{th} measurement occasion
Age_{ij} – student's age measured from age 12
γ_{00} – average initial level at t=0 (age 12)
γ_{10} – average rate of change
ζ_{0i} – variation around average initial level
ζ_{1i} – variation around average rate of change

APPENDIX

TABLE 5.3. Correlation matrix of estimates of initial levels and rates of change from individual growth models in boys and girls, NDIT Study, Montréal, Canada, 1999/2000-2004

Boys	Age	Height	Height x Age	BMI	BMI x Age	WC	WC x Age	Triceps skinfolds	Triceps skinfolds x Age	Subscap. skinfolds
Age	1.00									
Height	0.17	1.00								
Height x Age	-0.83	-0.51	1.00							
BMI	0.19	-0.26	0.12	1.00						
BMI x Age	-0.36	0.22	-0.13	-0.68	1.00					
Waist circumference	0.26	-0.35	0.20			1.00				
Waist circumference x Age	-0.41	0.27	-0.27			-0.67	1.00			
Triceps skinfolds	0.21	0.00	-0.02					1.00		
Triceps skinfolds	-0.28	0.05	-0.01					-0.69	1.00	

x Age										
Subscap. skinfolds	0.13	-0.13	0.05							1.00
Subscap. skinfolds x Age	-0.17	0.20	-0.14							-0.69

Girls	**Age**	**Height**	**Height x Age**	**BMI**	**BMI x Age**	**WC**	**WC x Age**	**Triceps skinfolds**	**Triceps skinfolds x Age**	**Subscap. skinfolds**
Age	1.00									
Height	0.40	1.00								
Height x Age	-0.87	-0.61	1.00							
BMI	0.11	-0.30	0.16	1.00						
BMI x Age	-0.26	0.24	-0.19	-0.66	1.00					
Waist circumference	0.17	-0.39	0.23			1.00				
Waist circumference x Age	-0.30	0.30	-0.33			-0.67	1.00			
Triceps skinfolds	0.11	-0.28	0.15					1.00		

Triceps skinfolds x Age	-0.19	0.28	-0.25					-0.74	1.00	
Subscap. skinfolds	0.07	-0.26	0.14							1.00
Subscap. skinfolds x Age	-0.16	0.26	-0.20							-0.73

Chapter 6: Manuscript II

Adolescence is characterized by sharp declines in physical activity.(56, 57) Prevention of declines in physical activity during adolescence is potentially a cost-effective strategy for preventing higher blood pressure in youth.(300) While increases in physical activity levels led to weight loss and reductions in SBP in clinical populations of overweight or hypertensive youth, no SBP reductions have been observed in non-clinical populations of youth exposed to interventions designed to increase participation in physical activity.(181, 186) There are few longitudinal cohort studies in non-clinical populations of youth that examined if there is a relation between changes in physical activity and SBP.(104) In this second manuscript, we assessed the association between changes in physical activity and BP in adolescence, and in addition we examined whether this association is mediated by changes in adiposity. This is one of the few longitudinal studies in this domain and the first study that assessed the role of changes in adiposity in the association between physical activity and SBP using several indicators of adiposity including BMI, waist circumference, and skinfold thickness.

TITLE: Declines in physical activity and higher systolic blood pressure in adolescence

SHORT TITLE: Physical activity, adiposity, systolic blood pressure in adolescence

AUTHORS: Katerina Maximova, Jennifer O'Loughlin, Gilles Paradis, James A. Hanley, John Lynch

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ABSTRACT

We examined the potential association between changes in number of moderate-to-vigorous physical activity (MVPA) sessions per week, adiposity and systolic blood pressure (SBP) during adolescence. SBP and anthropometry were assessed biannually (1999/2000, 2002, 2004) in a cohort of 1293 adolescents aged 12-13 years in 1999. Self-report 7-day recalls of MVPA sessions ≥5 minutes were collected every three months over five years. Estimates of initial level and rate of decline in number of MVPA sessions per week from individual growth models were used as predictors of SBP in linear regression models. A decline of one MVPA session per week with each year of age was associated with 0.29 and 0.19 mmHg higher SBP in girls and boys in early adolescence (12.8 to 15.1 years old), and 0.40 and 0.18 mmHg higher SBP in late adolescence (15.2 to 17.0 years old). The associations were not attenuated by changes in body mass index, waist circumference, or skinfold thickness in girls during late adolescence. Although weaker, associations were evident in boys during late adolescence as well as in both girls and boys during early adolescence. Results of this study support prevention of declines in MVPA during adolescence to prevent higher blood pressure in youth.

KEYWORDS: physical activity, blood pressure, adiposity, adolescents, epidemiology

BACKGROUND

Physical inactivity in adulthood is associated with a two-fold increase in the risk of elevated blood pressure and CVD.(162) Yet the majority of adults in industrialised countries do not meet recommended physical activity levels.(301) Although physical activity levels are highest among youth, they decline markedly during adolescence.(56, 57) Less than ten percent of Canadian youth aged 5-19 years attain the current recommendations of at least 90 minutes of moderate-to-vigorous activity, accumulated in bouts of at least 5 to 10 minutes, daily.(149, 150)

Systolic blood pressure (SBP) increases by 1-2 mmHg per year during childhood and adolescence.(34) Prevention of declines in physical activity during adolescence is potentially a cost-effective prevention strategy for preventing higher blood pressure in youth.(300) Short-term (2-12 weeks) increases in physical activity levels have been observed to result in SBP reductions of 1-6 mmHg,(165, 172) at least in clinical populations of obese or hypertensive youth.(173) However, no SBP reductions were observed in non-clinical populations of youth exposed to school-based interventions designed to increase participation in physical activity for at least one year.(181, 186) There are few longitudinal data in non-clinical populations of youth that examined if there is a relation between changes in habitual, rather than short-term, physical activity and SBP.(104)

Adiposity is a strong predictor of SBP in youth, independent of physical activity.(70) Since the inclusion of BMI attenuated the association between physical activity and SBP in some cross-sectional pediatric studies,(226, 227) it has been hypothesized that the relation between these two variables is mediated, at least in part, by adiposity.(152) However, no longitudinal study to date has assessed the role of changes in adiposity in the potential association between physical activity and SBP using several indicators of adiposity such as BMI, waist circumference, and skinfold thickness.

Adolescence is a period of rapid growth and behavioural changes, during which blood pressure, height, weight and body fat increase rapidly,(53) and physical activity levels decline sharply.(57) Increased understanding of the potential association between physical activity and SBP in general populations of youth is needed.(302) The objective of this study was to assess the potential association between changes in physical activity and blood pressure in adolescents, and to assess whether this potential association is mediated by changes in adiposity.

METHODS

Study Population

The Nicotine Dependence in Teens (NDIT) Study is an ongoing prospective cohort of 1293 grade 7 students aged 12-13 years at baseline (55.4 percent of those eligible), recruited in Fall 1999 in a convenience sample of 10 Montréal secondary schools.(289) Schools were selected to include a mix of French and English schools, schools located in urban, suburban, and rural areas, and in high, medium and low socioeconomic neighbourhoods. All students provided assent and their parents/guardians provided signed informed consent. The Institutional Review Boards at McGill University and Centre de recherche du Centre hospitalier de l'Université de Montréal approved the study protocol. Of 1293 students, 424 (32.8 percent) were lost to follow-up because they either refused to continue to participate (n=83) or moved (n=341). We use information from 19 waves of data collection in the first five years of follow-up (1999/2000-2004).

Students completed questionnaires at school every three months during the 10-month school year (September to June) in English or French. The questionnaires were translated from English into French and then back-translated, with adjustments made when the back-translation indicated divergent meaning. The number of moderate-to-vigorous physical activity (MVPA) sessions per week was assessed in each of the 19 waves of data collection between 1999/2000 and 2004. SBP and anthropometry were measured three times (Fall 1999/Winter 2000, Spring 2002, and Spring 2004). The relationships among physical activity, adiposity and SBP in adolescence are confounded by pubertal maturation.(287, 303) To mitigate the lack of measures of puberty in NDIT Study, we stratified the analyses by sex because pubertal maturation begins and ends earlier in girls than boys.(303) Since almost all girls complete pubertal maturation by age 15,(298) we also divided the follow-up time into two periods corresponding to early (mean age 12.8 to 15.1 years) and late adolescence (mean age 15.2 to 17.0 years) on the premise that the second period may be less confounded by pubertal maturation.

The analysis pertaining to early adolescence was based on SBP and anthropometry data collected in 1999/2000 and 2002, and repeated assessments of MVPA sessions from 12 waves collected during this time. The analysis pertaining to late adolescence was based on SBP and anthropometry data collected in 2002 and 2004, and repeated assessments of MVPA sessions from 8 waves collected during this time (Figure 6.1).

Measures

Students completed a 7-day recall checklist that asked them to report for each day of the preceding week (Monday to Sunday) each activity they engaged in for ≥5 minutes outside the regular school gym class. The checklist was adapted from the Weekly Activity Checklist(274) to reflect common activities engaged in by adolescents in Montréal. The original instrument correlated with accelerometer-measured physical activity in youth ($r=0.34$, $p<0.01$) and its 3-day test-retest reliability was $r=0.74$.(275) The test-retest reliability of the adapted checklist was examined in a subsample of 76 students, who completed it twice two weeks apart. The correlation between repeated measures was $r=0.73$, which is comparable to the correlation of $r=0.76$ observed with repeated measures using accelerometers in youth.(276) The adapted checklist also showed evidence of convergent-construct validity with energy intake.(277) The number of MVPA sessions per week was the sum of 23 activities,(278) defined as activities with estimated energy costs of over 4.8 metabolic equivalent values,(279-281) including bicycling, swimming/diving, basketball, baseball/softball, footfall, soccer, racket sports, ice/ball hockey, jumping rope, downhill skiing, cross-country skiing, ice skating, rollerblading/skateboarding, exercise/physical conditioning, ball playing, track and field, playing games, jazz/classical ballet, outdoor play, karate/judo/tai chi, boxing/wrestling, mixed walking, running/jogging.

Blood pressure was assessed in the sitting position, on the right arm after voiding and a five-minute rest period with an automated oscillometric device (Dinamap XL, model CR9340, Critikon Co., Tampa, FL) by technicians trained and certified according to a standardized protocol.(273) Oscillometric devices were calibrated against a mercury sphygmomanometer before each data collection period. A minimum of three blood pressure readings were recorded for each student at one-minute intervals. If the difference between the second and third readings was greater than 20 mmHg and 10 mmHg for systolic and diastolic blood pressure respectively, forth and fifth readings were taken. To reduce blood pressure reactivity/habituation (i.e., "white coat" effect), the first reading was not considered.(114) The mean value of the two readings with the least difference was calculated from the remaining readings.

Anthropometric measurements were collected with students dressed in light clothing without shoes using a stadiometer (model 214 Road Rod, Seca Corp., Hanover, MD) for height, a scale (floor model 761, Seca Corp.) for weight, Lange-type Baseline Skinfold calipers (AMG Medical Inc., Montréal, Canada) for skinfold thickness, and a standard tape measure just above the uppermost border of the right ilium at the end of normal expiration for waist circumference. Measurements were recorded to the nearest 0.1 cm for height, 0.2 kg for weight, 0.1 cm for waist circumference, and 0.5 mm for skinfold thickness. Two measurements were obtained for each participant. A third measurement was taken if the difference between the first two measurements was greater than 0.5 cm for height, 0.2 kg for weight, 0.5 cm for waist circumference, and 1 mm for skinfold thickness. All anthropometric measurements were repeated systematically on every tenth student to assess inter-rater reliability (ICC=0.99 for height and weight, 0.98 for waist circumference, and 0.95 for triceps and 0.96 for subscapular skinfold thickness). For all anthropometric measurements, the mean value of two measurements with the least difference was calculated. BMI was computed as weight/height^2 (kg/m^2). Skinfold thickness was the sum of triceps and subscapular skinfold thickness.

Statistical Analysis

The mean number of repeated assessments of MVPA sessions per student was 9.5 (SD=1.96) (of a possible 12) in early adolescence, and 6.7 (SD=1.37) (of a possible 8) in late adolescence. Repeated assessments of MVPA sessions for each student were analyzed using individual growth modeling with student's age representing time. To represent each student's pattern of number of MVPA sessions over time during early and late adolescence, estimates of initial level (i.e., intercept) and rate of change over time (i.e., slope) were derived from individual growth models for each student, for each of the two periods. Age was "centered" on 12 years for the early adolescence models, and on 15 years for the late adolescence models to facilitate the interpretation of the intercept as an estimate of physical activity at age 12 or 15 years, rather than at age zero.(140)

Month of data collection was used to adjust for seasonal variation in the number of MVPA sessions.(278)

The estimates of each student's intercept and slope for the number of MVPA sessions per week were then used as predictors of blood pressure at the end of early (mean age 15.1 years) and late adolescence (mean age 17.0 years). These associations were examined using two sets of sex-specific linear regression models for each of the two study periods. Model 1 included estimates of initial level and the rate of decline in the number of MVPA sessions per week; initial (baseline) SBP; initial BMI; initial height, change in height, an interaction between initial height and change in height; age at the time of SBP measurement; and smoking (self-reported number of cigarettes smoked in the past week (preceding data collection) that was averaged over follow-up). To examine if these associations were mediated by changes in adiposity, Model 2 also included change in BMI during the period and an interaction between initial BMI and change in BMI. Height and change in height were used as crude proxy measures of the maturation process.(287) The interaction terms for height and BMI were added since height and weight may increase faster in adolescents with a higher initial height or BMI.(210) These two models were repeated for the two other adiposity indicators (waist circumference and skinfold thickness).

RESULTS

Selected characteristics of participants in whom blood pressure was measured are presented in Table 6.1. Despite seasonal variation,(278) the mean number of

MVPA sessions per week declined during follow-up in girls and boys (Figures 6.2.1 and 6.2.2). Girls engaged in 11.7 MVPA sessions per week on average at age 12 and 8.9 MVPA sessions per week on average at age 15 years. The number of MVPA sessions declined by 0.8 and 1.5 sessions per week on average in girls during early and late adolescence (Table 6.2). Boys engaged in 16.7 MVPA sessions per week on average at age 12 and 14.0 MVPA sessions per week on average at age 15 years. The number of MVPA sessions declined by 0.9 and 2.3 sessions per week on average in boys during early and late adolescence.

Estimates of initial level and rate of decline in the number of MVPA sessions per week were inversely associated with SBP. In early adolescence, a decline of one MVPA session per week with each year of age was associated with 0.29 and 0.19 mmHg higher SBP in girls and boys (Table 6.3, Model 1A). In late adolescence, a decline of one MVPA session per week with each year of age was associated with 0.40 and 0.18 mmHg higher SBP in girls and boys (Table 6.4, Model 1A).

The association between changes in adiposity and SBP was significant in early and late adolescence. In early adolescence, girls whose BMI increased by one unit, waist circumference by one cm, or skinfold thickness by one mm had 2.74, 1.21 and 0.53 mmHg higher SBP than those who did not (Table 6.3, Models 2A, 2B, 2C). Boys whose BMI increased by one unit, waist circumference by one cm, or skinfold thickness by one mm had 3.87, 0.64 and 0.64 mmHg higher SBP than those who did not. In late adolescence, girls whose BMI increased by one unit, waist circumference by one cm, or skinfold thickness by one mm had 1.50, 1.49

and 0.19 mmHg higher SBP than those who did not (Table 6.4, Models 2A, 2B, 2C). Boys whose BMI increased by one unit, waist circumference by one cm, or skinfold thickness by one mm had 0.52, 0.27 and 0.14 mmHg higher SBP than those who did not.

The magnitude of the associations between initial level and rate of decline in the number of MVPA sessions per week and SBP remained unchanged in late adolescence in girls after adjusting for changes in BMI, waist circumference, or skinfold thickness. However, the association was attenuated in boys (Table 6.3). The association between the rate of decline in the number of MVPA sessions per week and SBP was reduced after adjusting for changes in skinfold thickness (Model 2C), but not the other adiposity indicators, in both girls and boys in early adolescence. Models that tested the associations between the number of MVPA sessions per week and diastolic blood pressure were less consistent, but provided similar results (data not shown).

DISCUSSION

We examined the potential association among changes in the number of MVPA sessions per week, adiposity and SBP during adolescence. Three key findings emerged from this study. First, declines in the number of MVPA sessions per week were inversely associated with SBP in youth. Second, increases in adiposity and declines in the number of MVPA sessions per week were each independently associated with higher SBP. Third, the associations between declines in the number of MVPA sessions per week and SBP were not mediated by contemporaneous changes in adiposity in girls during late adolescence. Albeit weaker, these associations were evident in boys during late adolescence as well as in both girls and boys during early adolescence.

Results of this study add to the limited literature on the longitudinal association between physical activity and SBP in youth. Changes in self-reported physical activity measured between age 12 and 15 years related inversely to changes in SBP in 459 adolescents in Northern Ireland.(214) In the Dietary Intervention Study in Childhood (DISC), self-reported physical activity increased over three years of follow-up and was also inversely related to SBP in 663 youth with elevated cholesterol at baseline, followed from ages 8-10 to 11-13 years.(215) Participation in MVPA declined over time in our study, and the rate of decline in late adolescence was twice that in early adolescence. This decline is consistent with the marked declines in physical activity previously reported in longitudinal studies of adolescents.(56, 57)

This study provides the first longitudinal evidence that declines in MVPA during adolescence were more pronounced in late adolescence and that a given decline in MVPA was associated with greater increases in SBP after age 15, even after adjusting for changes in adiposity and other covariates. This finding is consistent with a previous cross-sectional study demonstrating that the importance of physical activity in blood pressure control increases with age, and becomes particularly important by age 15.(304)

This study also provides the first longitudinal evidence that the relationship between MVPA and SBP in youth was generally not mediated by some components of adiposity in girls during late adolescence. Previous longitudinal studies indicate that self-reported physical activity was inversely related to BMI,(212) and that BMI was a strong predictor of blood pressure in youth, independent of physical activity, accounting for a substantial proportion of blood pressure variability.(226, 227) Although the inclusion of BMI attenuated the association between blood pressure and physical activity in some cross-sectional studies, we found that the associations remained unchanged after adjustment for change in BMI. Since the BMI measure does not discriminate between changes in muscle versus fat mass, we examined other indicators of adiposity, including waist circumference and skinfold thickness. Although changes in all three adiposity indicators significantly related to SBP in our study, none mediated the associations of interest in girls during late adolescence. Since fat mass correlates closely with pubertal maturation and increases up to age 15,(305) attenuation of the associations of interest by changes in adiposity indicators during early adolescence and in boys likely reflects confounding by pubertal maturation.

The key strength of this study was the large number of data points for the number of MVPA sessions. Since the beneficial effect of being physically active on blood pressure may not manifest quickly, it has been suggested that frequent assessments of physical activity over longer periods of time are required in order to adequately assess the longitudinal relations between physical activity and blood pressure in youth.(306) Yet few longitudinal studies examined this association in general populations of youth using multiple data points. In this study, the large number of data points facilitated modeling of longitudinal patterns (trajectories) of the number of MVPA sessions in early and late adolescence using individual growth models.

A major strength of this study is that our measure of MVPA preceded the SBP measures. Longitudinal designs that relate changes in outcomes to time-dependent factors that change concurrently with the outcome have been criticized for their weak claims about the direction of causality.(307) Our study design however allowed estimation of the longitudinal patterns of the number of MVPA sessions in early and late adolescence, which preceded SBP measurement at the end of each period. Our design may therefore allow for stronger claims about the causal relations between physical activity and SBP in youth.

Our measure of MVPA sessions of ≥5 minutes represents bouts of more intense activity that are accumulated over the course of the week. Recent evidence suggests that accumulating MVPA in short or medium bouts of ≥5 minutes was protective against overweight and elevated blood pressure in youth.(207, 208, 308) A minimum of three (and up to five) SBP readings on each measurement occasion for each adolescent in NDIT Study is also a strength since multiple readings improve the reliability of SBP, which can be challenging in youth.(299) Lastly, in addition to BMI, our study included waist circumference and skinfold thickness, which can better discriminate between changes in muscle versus fat mass than BMI.(205)

Although previous studies reported that the link between fitness and SBP was more robust than the link between physical activity and SBP,(129, 309) low physical fitness is considered an indicator of genetic predisposition to low fitness levels and high cardiovascular risk and may not reflect individual physical activity behaviour.(205) On the other hand, physical inactivity is considered an indicator of unhealthy behaviour.(172) A recent population-based cross-sectional study of objectively measured physical activity and SBP concluded that the quantity of exercise was more important than its intensity.(208) Moreover, the most recent expert guidelines focus on the total amount of physical activity and exercise, rather than its intensity.(310)

Limitations of this study include the use of MVPA measures based on self-report, which may be prone to recall and social desirability biases, leading to misclassification. Reporting each MVPA session of ≥5 minutes may have overestimated physical activity levels. However, the requirement to recall all MVPA sessions over the past week likely underestimated student's activity levels. This possible misreporting may change the direction of the bias in either direction, however. Moreover, repeated assessments of physical activity over time reduce measurement error and generally provide a more valid estimate of physical activity levels in youth.(311) Although our measure of MVPA is based on the energy costs developed for adults, the energy expenditure in older adolescents (aged 15-18 years) is comparable to that observed in adults.(281) A serious limitation of this study is the lack of a puberty measure. To mitigate the lack of data on puberty, we conducted sex-specific analyses and studied the associations of interest in both early and late adolescence on the premise that the associations in girls and during late adolescence may be less confounded by pubertal maturation.(298, 312) We also adjusted the associations under study for both height and changes in height, which we considered to be crude proxy measures of the maturation process,(287) since the growth spurt in height begins and ends earlier in girls than in boys.(298) In spite of this, the associations between changes in the number of MVPA sessions and SBP were strongest in girls during late adolescence.

In conclusion, declines in the number of MVPA sessions per week during adolescence were inversely associated with SBP in youth. A decline of one MVPA session per week with each year of age was associated with 0.29 and 0.19 mmHg higher SBP in girls and boys in early adolescence, and 0.40 and 0.18 mmHg higher SBP in late adolescence. These associations were not attenuated by contemporaneous changes in adiposity in girls during late adolescence. Although weaker, these associations were evident in boys during late adolescence as well as in both girls and boys during early adolescence. These results may have public health importance because they suggest that by preventing declines in physical activity during adolescence through continued participation in MVPA, there is a potential to prevent part of blood pressure increases in youth.

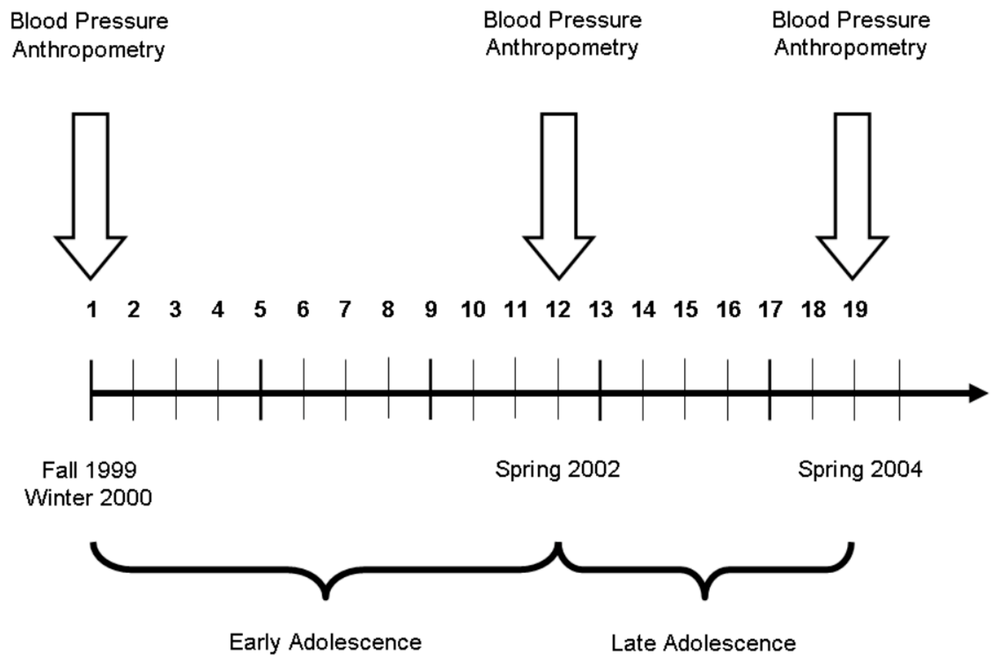

FIGURE 6.1. The Nicotine Dependence in Teens (NDIT) Study data collection waves, Montréal, Canada, 1999/2000-2004

Abbreviations: NDIT, The Nicotine Dependence in Teens Study.

Note: Follow-up every 3 months during 10-month school year (September to June) for 5 years.

TABLE 6.1. Selected characteristics of adolescent girls and boys at three time points when systolic blood pressure was measured, NDIT Study, Montréal, Canada, 1999/2000-2004

	Early Adolescence											
					Late Adolescence							
	Wave 1 (Fall 1999/Winter 2000)				Wave 12 (Spring 2002)				Wave 19 (Spring 2004)			
	Girls (n=617)		Boys (n=575)		Girls (n=491)		Boys (n=462)		Girls (n=410)		Boys (n=389)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Age, years	12.7	(0.6)	12.8	(0.6)	15.1	(0.4)	15.2	(04)	16.9	(0.4)	17.0	(0.4)
Systolic blood pressure, mmHg	104.4	(9.4)	105.3	(10.7)	103.8	(9.8)	108.7	(10.5)	106.0	(9.9)	114.6	(11.0)
Diastolic blood pressure, mmHg	56.7	(6.4)	55.8	(6.1)	57.2	(6.3)	56.9	(5.6)	58.4	(6.1)	59.2	(6.4)
Height, cm	155.7	(6.7)	156.2	(8.7)	162.0	(5.9)	171.3	(7.3)	163.2	(6.0)	175.6	(6.5)
Weight, kg	48.6	(11.7)	49.1	(11.5)	56.6	(11.1)	63.5	(12.1)	59.2	(11.3)	69.8	(11.9)
BMI, kg/m^2	20.0	(3.9)	20.1	(3.8)	21.6	(3.8)	21.6	(3.6)	22.3	(4.1)	22.8	(4.1)
Waist circumference, cm	69.8	(9.8)	72.6	(10.3)	74.2	(9.2)	77.0	(9.3)	76.0	(9.2)	79.9	(9.3)
Triceps skinfold thickness, mm	14.9	(5.6)	13.3	(6.4)	19.5	(6.4)	12.8	(5.9)	22.4	(7.2)	14.3	(7.3)
Subscapular skinfold thickness, mm	10.8	(5.3)	9.6	(5.9)	14.1	(5.9)	10.4	(4.7)	16.9	(6.6)	13.5	(6.9)

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; SD, standard deviation; BMI, body mass index.

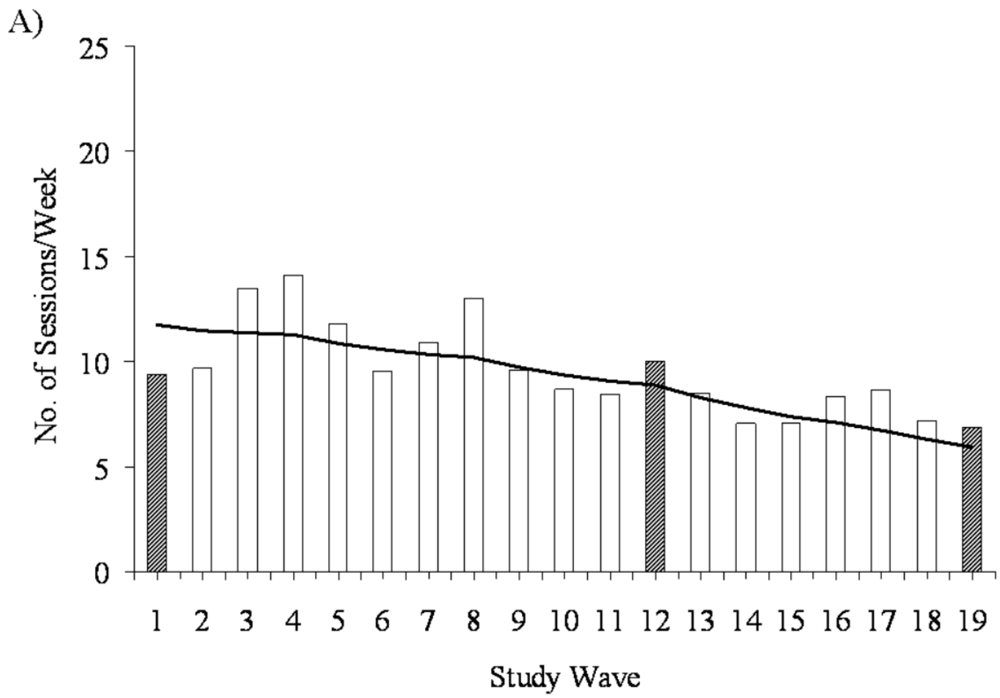

FIGURE 6.2.1. Observed and seasonally adjusted number of moderate-to-vigorous physical activity sessions per week during adolescence in girls, NDIT Study, Montréal, Canada, 1999/2000-2004

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; No., number.

Key to figure: Each bar represents study waves 1 to 19 which occurred every 3 months during 10-month school year (September to June) for 5 years. Patterned bars represent study waves during which blood pressure and anthropometry were measured. Study waves 1, 2, 6, 7, 10, 11, 14, 15, 18, and 19 occurred during winter months (January to March). The line of best fitted values for the number of moderate-to-vigorous physical activity sessions per week, adjusted for seasonal variations, from the individual growth models.

B)

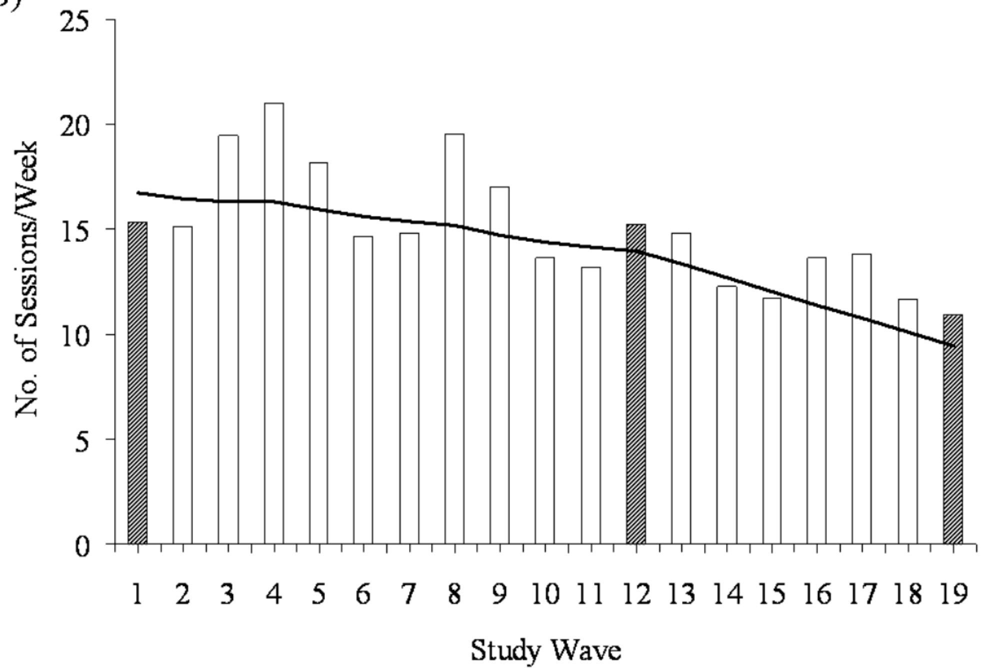

FIGURE 6.2.2. Observed and seasonally adjusted number of moderate-to-vigorous physical activity sessions per week during adolescence in boys, NDIT Study, Montréal, Canada, 1999/2000-2004

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; No., number.

Key to figure: Each bar represents study waves 1 to 19 which occurred every 3 months during 10-month school year (September to June) for 5 years. Patterned bars represent study waves during which blood pressure and anthropometry were measured. Study waves 1, 2, 6, 7, 10, 11, 14, 15, 18, and 19 occurred during winter months (January to March). The line of best fitted values for the number of moderate-to-vigorous physical activity sessions per week, adjusted for seasonal variations, from the individual growth models.

TABLE 6.2. Estimated mean initial level[a] and mean rate of decline[a] in number of moderate-to-vigorous physical activity sessions per week in early and late adolescence in girls and boys, NDIT Study, Montréal, Canada, 1999/2000-2004

	Total		**Girls**		**Boys**	
	Coeff	**95% CI**	**Coeff**	**95% CI**	**Coeff**	**95% CI**
Early adolescence						
Initial level, β_{0i}	14.14	13.31, 14.98	11.73	10.80, 12.66	16.73	15.36, 18.09
Rate of decline, β_{1i}	-0.84	-1.10, -0.58	-0.75	-1.04, -0.46	-0.94	-1.38, -0.50
Late adolescence						
Initial level, β_{0i}	11.30	10.54, 12.07	8.87	8.06, 9.69	13.97	12.70, 15.25
Rate of decline, β_{1i}	-1.85	-2.17, -1.53	-1.49	-1.85, -1.14	-2.26	-2.80, -1.71

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; CI, confidence interval, No., number.

[a] Mean initial level (β_{0i}) and mean rate of decline (β_{1i}) in the number of moderate-to-vigorous physical activity sessions per week, adjusted for seasonal variations, from the individual growth models.

TABLE 6.3. Factors associated with systolic blood pressure (mmHg) at the end of early adolescence in girls and boys (age 15), NDIT Study, Montréal, Canada, 1999/2000-2004

Girls

	Model 1A		**Model 2A**		**Model 1B**		**Model 2B**		**Model 1C**		**Model 2C**	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
SBP, mmHg												
initial level	0.56	0.53, 0.58	0.55	0.53, 0.58	0.55	0.52, 0.58	0.56	0.53, 0.58	0.56	0.54, 0.59	0.57	0.55, 0.60
MVPA sessions, No.												
initial level	-0.11	-0.15, -0.08	-0.12	-0.15, -0.08	-0.11	-0.15, -0.08	-0.11	-0.15, -0.08	-0.12	-0.15, -0.08	-0.10	-0.13, -0.06
rate of decline	0.29	0.06, 0.52	0.30	0.07, 0.52	0.30	0.07, 0.52	0.33	0.10, 0.55	0.27	0.04, 0.50	0.17	-0.05, 0.40
Age, years	-0.06	-0.72, 0.61	-0.14	-0.79, 0.52	-0.09	-0.76, 0.57	-0.33	-0.99, 0.33	-0.13	-0.80, 0.54	0.29	-0.36, 0.94
Height, cm												
initial level	0.13	0.06, 0.21	0.12	0.05, 0.19	0.12	0.05, 0.19	0.10	0.03, 0.17	0.15	0.07, 0.22	0.14	0.07, 0.21
Δ height	-0.24	-1.53, 1.06	-0.35	-1.63, 0.92	-0.26	-1.56, 1.03	-0.34	-1.62, 0.93	-0.17	-1.47, 1.12	0.44	-0.82, 1.69
interaction	0.00	0.00, 0.01	0.00	0.00, 0.01	0.00	0.00, 0.01	0.00	0.00, 0.01	0.00	-0.01, 0.01	0.00	-0.01, 0.01
Smoking, cigarettes/week	0.02	0.00, 0.04	0.03	0.013, 0.04	0.02	0.00, 0.04	0.02	0.01, 0.04	0.02	0.01, 0.04	0.03	0.02, 0.05
BMI, kg/m^2												
initial level	0.05	-0.02, 0.11	0.27	0.19, 0.35								
Δ BMI			2.74	2.02, 3.45								
interaction			-0.08	-0.11, -0.05								

Waist circumference, cm												
initial level					0.04	0.01, 0.06	0.15	0.12, 0.18				
Δ waist circumference							1.21	0.92, 1.50				
interaction							-0.01	-0.02, -0.01				
Skinfold thickness, mm												
initial level									-0.01	-0.03, 0.02	0.10	0.07, 0.13
Δ skinfold thickness											0.53	0.45, 0.61
interaction											-0.01	-0.01, -0.01
R-squared	0.30		0.33		0.30		0.33		0.30		0.35	

Boys

	Model 1A		**Model 2A**		**Model 1B**		**Model 2B**		**Model 1C**		**Model 2C**	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
SBP, mmHg												
initial level	0.54	0.52, 0.57	0.54	0.51, 0.56	0.55	0.53, 0.58	0.55	0.53, 0.58	0.56	0.53, 0.59	0.55	0.53, 0.58
MVPA sessions, No.												
initial level	-0.02	-0.05, 0.00	-0.05	-0.07, -0.02	-0.02	-0.05, 0.00	-0.03	-0.06, -0.01	-0.02	-0.05, 0.00	-0.02	-0.05, 0.00
rate of decline	0.19	0.03, 0.35	0.19	0.03, 0.35	0.19	0.03, 0.35	0.16	0.00, 0.33	0.18	0.02, 0.35	0.11	-0.05, 0.27
Age, years	0.51	-0.12, 1.14	0.78	0.16, 1.39	0.46	-0.18, 1.09	0.79	0.16, 1.41	0.38	-0.26, 1.01	0.31	-0.31, 0.93

Height, cm												
initial level	0.11	0.03, 0.19	0.00	-0.08, 0.08	0.08	-0.00, 0.16	0.05	-0.03, 0.13	0.07	-0.01, 0.16	0.07	-0.01, 0.16
Δ height	0.60	-0.22, 1.42	-0.32	-1.14, 0.49	0.36	-0.46, 1.18	0.24	-0.58, 1.05	0.13	-0.70, 0.95	0.41	-0.40, 1.22
interaction	0.00	-0.01, 0.00	0.00	-0.00, 0 .01	0.00	-0.01, 0.00	0.00	-0.01, 0.00	0.00	0.00, 0.01	0.00	-0.01, 0.00
Smoking, cigarettes/week	-0.04	-0.06, -0.02	-0.03	-0.06, -0.01	-0.04	-0.06, -0.01	-0.03	-0.05, -0.01	-0.03	-0.06, -0.01	-0.02	-0.04, 0.00
BMI, kg/m^2												
initial level	0.28	0.20, 0.36	0.63	0.52, 0.74								
Δ BMI			3.87	3.02, 4.73								
interaction			-0.13	-0.17, -0.09								
Waist circumference, cm												
initial level					0.05	0.03, 0.08	0.13	0.10, 0.17				
Δ waist circumference							0.64	0.35, 0.92				
interaction							-0.01	-0.01, 0.00				
Skinfold thickness, mm												
initial level									0.00	-0.02, 0.02	0.07	0.05, 0.10
Δ skinfold thickness											0.64	0.55, 0.72
interaction											-0.01	-0.01, 0.00
R-squared	0.33		0.36		0.33		0.34		0.32		0.36	

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; CI, confidence interval; SBP, systolic blood pressure; MVPA, moderate-to-vigorous physical activity; No., number; BMI, body mass index.

Notes: Initial SBP, height, BMI, waist circumference and skinfold thickness refer to respective variable value at baseline data collection in 1999/2000 (wave 1). Change in height, BMI, waist circumference and skinfold thickness represent an absolute difference between 1999/2000 and 2002 (waves 1 and 12). Interactions refer to an interaction between respective variable initial level and change in that variable between 1999/2000 and 2002 (waves 1 and 12). Initial level and rate of decline in number of MVPA sessions per week refer to individual β_{0i} and β_{1i}, adjusted for seasonal variations, from the individual growth models (see Methods).

Model 1A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI
Model 2A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI + change in BMI + BMI interaction

Models 1B and 2B are as above except that waist circumference was used as a measure of adiposity.
Models 1C and 2C are as above except that the sum of skinfold thickness was used as a measure of adiposity.

TABLE 6.4. Factors associated with systolic blood pressure (mmHg) at the end of late adolescence in girls and boys (age 17), NDIT Study, Montréal, Canada, 1999/2000-2004

Girls

	Model 1A		**Model 2A**		**Model 1B**		**Model 2B**		**Model 1C**		**Model 2C**	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
SBP, mmHg												
initial level	0.58	0.55, 0.61	0.59	0.57, 0.62	0.58	0.56, 0.61	0.59	0.56, 0.62	0.60	0.57, 0.62	0.61	0.59, 0.64
MVPA sessions, No.												
initial level	-0.05	-0.11, 0.01	-0.06	-0.12, -0.01	-0.04	-0.10, 0.01	-0.05	-0.11, 0.00	-0.04	-0.10, 0.02	-0.04	-0.10, 0.02
rate of decline	0.40	0.13, 0.67	0.55	0.29, 0.81	0.40	0.13, 0.67	0.43	0.17, 0.69	0.45	0.18, 0.72	0.40	0.13, 0.67
Age, years	0.46	-0.32, 1.23	0.31	-0.44, 1.06	0.60	-0.17, 1.37	0.16	-0.60, 0.93	0.76	-0.02, 1.53	0.61	-0.16, 1.37
Height, cm												
initial level	0.29	0.23, 0.35	0.20	0.14, 0.26	0.25	0.19, 0.31	0.18	0.12, 0.24	0.28	0.22, 0.34	0.26	0.20, 0.32
Δ height	20.06	14.43, 25.69	14.20	8.70, 19.70	19.05	13.42, 24.67	16.92	11.44, 22.40	18.59	12.92, 24.25	18.64	13.06, 24.21
interaction	-0.12	-0.16, -0.09	-0.09	-0.12, -0.05	-0.12	-0.15, -0.08	-0.10	-0.14, -0.07	-0.11	-0.15, -0.08	-0.11	-0.15, -0.08
Smoking, cigarettes/week	0.02	0.01, 0.03	0.02	0.01, 0.03	0.02	0.01, 0.03	0.02	0.01, 0.03	0.02	0.01, 0.03	0.02	0.01, 0.04
BMI, kg/m^2												
initial level	0.30	0.22, 0.37	0.26	0.18, 0.34								
Δ BMI			1.50	0.73, 2.27								
interaction			0.11	0.08, 0.14								

Waist circumference, cm												
initial level					0.11	0.08, 0.14	0.12	0.08, 0.15				
Δ waist circumference							1.49	1.07, 1.90				
interaction							0.02	0.02, 0.03				
Skinfold thickness, mm												
initial level									0.03	0.01, 0.05	0.06	0.03, 0.09
Δ skinfold thickness											0.19	0.10, 0.28
interaction											0.00	0.00, 0.00
R-squared	0.41		0.46		0.41		0.44		0.40		0.42	

Boys

	Model 1A		**Model 2A**		**Model 1B**		**Model 2B**		**Model 1C**		**Model 2C**	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
SBP, mmHg												
initial level	0.57	0.54, 0.60	0.59	0.55, 0.62	0.57	0.54, 0.61	0.58	0.55, 0.61	0.58	0.54, 0.61	0.59	0.55, 0.62
MVPA sessions, No.												
initial level	0.00	-0.04, 0.04	0.00	-0.04, 0.04	0.00	-0.04, 0.04	0.01	-0.03, 0.05	0.01	-0.04, 0.05	0.02	-0.02, 0.06
rate of decline	0.18	-0.04, 0.39	0.12	-0.09, 0.34	0.18	-0.04, 0.40	0.11	-0.10, 0.33	0.17	-0.04, 0.39	0.12	-0.09, 0.33
Age, years	-0.58	-1.44, 0.28	-0.16	-1.00, 0.69	-0.51	-1.37, 0.35	-0.29	-1.15, 0.56	-0.52	-1.39, 0.34	-0.24	-1.09, 0.62

Height, cm												
initial level	0.02	-0.06, 0.09	0.05	-0.02, 0.12	0.00	-0.08, 0.07	-0.01	-0.08, 0.07	0.02	-0.06, 0.09	0.03	-0.05, 0.10
Δ height	0.76	-1.31, 2.82	0.60	-1.42, 2.63	0.83	-1.23, 2.90	0.73	-1.32, 2.78	0.56	-1.51, 2.63	1.03	-1.03, 3.08
interaction	0.00	-0.02, 0.01	0.00	-0.01, 0.01	0.00	-0.02, 0.01	0.00	-0.02, 0.01	0.00	-0.02, 0.01	-0.01	-0.02, 0.01
Smoking, cigarettes/week	0.03	0.01, 0.05	0.06	0.04, 0.08	0.03	0.01, 0.05	0.05	0.03, 0.07	0.04	0.02, 0.06	0.04	0.02, 0.06
BMI, kg/m^2												
initial level	0.27	0.17, 0.36	0.30	0.20, 0.40								
Δ BMI			0.52	-0.31, 1.35								
interaction			0.02	-0.01, 0.06								
Waist circumference, cm												
initial level					0.11	0.08, 0.15	0.13	0.09, 0.16				
Δ waist circumference							0.27	-0.14, 0.69				
interaction							0.01	0.00, 0.01				
Skinfold thickness, mm												
initial level									0.07	0.04, 0.10	0.06	0.02, 0.09
Δ skinfold thickness											0.14	0.03, 0.25
interaction											0.00	0.00, 0.00
R-squared	0.31		0.34		0.31		0.32		0.31		0.32	

Abbreviations: NDIT, The Nicotine Dependence in Teens Study; CI, confidence interval; SBP, systolic blood pressure; MVPA, moderate-to-vigorous physical activity; No., number; BMI, body mass index.

Notes: Initial SBP, height, BMI, waist circumference and skinfold thickness refer to respective variable value at data collection in 2002 (wave 12). Change in height, BMI, waist circumference and skinfold thickness represent an absolute difference between 2002 and 2004 (waves 12 and 19). Interactions refer to an interaction between respective variable initial level and change in that variable between 2002 and 2004 (waves 12 and 19). Initial level and rate of decline in number of MVPA sessions per week refer to individual β_{0i} and β_{1i}, adjusted for seasonal variations, from the individual growth models (see Methods).

Model 1A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI
Model 2A: SBP = MVPA β_{0i} + MVPA β_{1i} + initial SBP + initial height + change in height + height interaction + smoking + initial BMI + change in BMI + BMI interaction

Models 1B and 2B are as above except that waist circumference was used as a measure of adiposity.
Models 1C and 2C are as above except that the sum of skinfold thickness was used as a measure of adiposity.

Chapter 7: Manuscript III

While previous studies demonstrated that excess weight gain and declining physical activity are detrimental for SBP in youth, prevention interventions in non-clinical populations of youth have had limited success. Although several interventions improved physical activity levels in general populations of youth,(181) these improvements were often short-term and were not sustained in the long run. Achieving and maintaining increased physical activity levels is challenging and requires substantial motivation. In the third and fourth manuscripts, we hypothesized that misperception of weight status among young people may be an important barrier to the success of prevention interventions targeting behaviour modification in youth. In the third manuscript, we examined the extent of weight status misperception in children and adolescents, and assessed whether living in an obesogenic environment may be associated with the degree of misperception. While previous studies have reported that actual weight status and perceptions of weight status often do not coincide among youth, this study is the first to identify factors associated with weight status misperception.

TITLE: Do you see what I see? Weight status misperception and exposure to obesity among children and adolescents

SHORT TITLE: Exposure to obesity and weight status misperception

AUTHORS: Katerina Maximova, Jennifer J. McGrath, Tracie Barnett, Jennifer O'Loughlin, Gilles Paradis, Marie Lambert

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ABSTRACT

Objective: Obesity prevention in childhood is important. However, changing children's lifestyle behaviors to reduce overweight is a substantial challenge. Accurately perceiving oneself as overweight/obese has been linked to greater motivation to change lifestyle behaviors. Children and adolescents may be less likely to perceive themselves as overweight/obese if they are exposed to overweight/obese people in their immediate environments. The present study examined whether youth who are exposed to overweight parents and schoolmates were more likely to misperceive their own weight status.

Design: The Québec Child and Adolescent Health and Social (QCAHS) Survey was a provincially representative, school-based survey of children and adolescents conducted between January and May 1999.

Subjects: 3665 children and adolescents (age 9, n = 1267; age 13, n = 1186; age 16, n = 1212) from 178 schools. Mean BMI was 17.5, 20.6, and 22.2 kg/m^2, respectively.

Measurements: Weight status misperception was calculated as the standardized difference between self-perception of weight status (Stunkard Body Rating Scale) and actual BMI (from measured height and weight). Exposure to obesity was based on parent and schoolmate BMI.

Results: Overweight and obese youth were significantly more likely to misperceive their weight compared with non-overweight youth ($p<0.001$). Multi-level modeling indicated that greater parent and schoolmate BMI were significantly associated with greater misperception (underestimation) of weight status among children and adolescents.

Conclusion: Children and adolescents who live in environments in which people they see on a daily basis, such as parents and schoolmates, are overweight/obese may develop inaccurate perceptions of what constitutes appropriate weight status. Targeting misperception may facilitate the adoption of healthy lifestyle behaviors and improve the effectiveness of obesity prevention interventions.

KEYWORDS: obesity, misperception, child, adolescent, parent, schoolmate, multi-level modeling, Québec

BACKGROUND

Over the last two decades, alarming increases in the prevalence of obesity worldwide have propelled this issue to the forefront of the public policy agenda, with obesity prevention becoming a top public health priority.(37, 313) The prevalence of childhood obesity has increased almost threefold during this time.(35, 38) Obesity prevention during childhood and adolescence is particularly important because obesity tracks into adulthood,(41) leading to elevated risks for hypertension, type 2 diabetes, osteoarthritis, coronary heart disease, congestive heart failure, stroke, breast and colon cancer, and premature death.(42, 145)

These dramatic increases in obesity are largely attributable to lifestyle behaviors including poor diet, physical inactivity, and sedentary behavior.(314) Obesity prevention interventions targeting these lifestyle behaviors (i.e., increasing physical activity, improving diet) have had limited success as the establishment of healthy behaviors is difficult to sustain in the long-term.(48-50) In a recent Cochrane review of 22 randomized controlled trials, Summerbell and colleagues (2005) found childhood obesity prevention interventions resulted in no reduction of overweight (i.e., body mass index, BMI) and only modest improvements in changing diet or exercise behaviors in the short-term.(50) Nonetheless, modification of these lifestyle behaviors continues to be recommended for obesity prevention in children.(46, 47)

One of the components of effective behavior change may be recognition on the part of the individual that their weight status exceeds normal weight and poses a health risk. Individuals may need to perceive themselves to be at risk and recognize their overweight to be a health problem in order to change their lifestyle behaviors. Accurately perceiving oneself as overweight or obese is considered an important cue for action and change, and has been linked to greater motivation to engage in healthy lifestyle behaviors.(249, 250) Growing evidence suggests that actual weight and perception of weight status often do not coincide, and that deviations between actual and perceived weight status are more common among overweight and obese individuals.(251-254) Among overweight adults, 43 percent of men and 18 percent of women perceived themselves to be of "healthy weight or underweight".(251-253) Among overweight youth, 58 percent of boys and 34 percent of girls perceived their weight to be "about right".(254) These studies underscore that significant proportions of individuals misperceive their overweight status. However, these studies were limited to cross-tabulations of weight status and BMI categories; and thus, they were unable to evaluate the determinants of misperception.

Misperception of overweight may be one explanation for the limited success of obesity prevention interventions. Theoretical models of health behavior change (cf. Health Belief Model,(255) Transtheoretical Model of Behavior Change,(256) Decisional Balance (258)) emphasize the necessity of perceiving oneself "at risk" as a prerequisite to behavior change. A recent application of the Transtheoretical Model demonstrated that the majority of children and adolescents were not ready for an obesity prevention intervention.(261) Not only were they not participating in healthy lifestyle behaviors, they did not meet national recommendations for physical activity, or for fruit and vegetable consumption, and most did not realize they needed to adopt these healthy behaviors. Healthy lifestyle behavior changes may be more likely to occur if youth recognize themselves as overweight or obese.

Due to the widespread media preoccupation with thinness and dieting, as well as the serious health problem of eating disorders, public health messages have emphasized healthy body images encouraging body acceptance.(315) Paradoxically, these messages may promote acceptance of overweight and obesity and conflict with the basic tenets of behavioral change theories. Irrespective of ideal body size preferences, when overweight youth misperceive their weight status and do not consider their weight to pose a health risk, they may be less likely to heed public health messages or to implement lifestyle behavior modifications.(251)

It is unclear what factors may influence misperception of weight status. It is plausible that youth may underestimate their weight status when they are exposed to overweight/obese people in their immediate environments at home and in school, resulting in a perceptual bias. In other words, when children's parents and schoolmates are overweight or obese, their own overweight status may seem normal by comparison. Recent evidence indicates that having a social network with a high prevalence of overweight is associated with weight gain among adults.(262) Obesogenic environment at home, defined as an environment that promotes excessive food intake and discourages physical activity,(263, 264) has also been linked to adolescent weight status.(265, 266) Adolescents who live in families that permit or model behaviors associated with excessive weight (e.g., poor diet, physical inactivity, considerable television viewing) are at increased risk for overweight and obesity in young adulthood.(266) However, little is known about how social contexts (e.g., school) influence youth's misperception of weight status. No research to date has examined whether exposure to overweight/obese people among those at home and in school is associated with greater misperception of weight status.

In the present study, we aim to investigate whether children and adolescents who live with overweight parents and attend schools with overweight schoolmates are more likely to misperceive (or underestimate) their weight status. Using a population-based sample, the specific study objectives were to assess (1) the extent to which children and adolescents' perception of their weight status concurs with measured weight and (2) whether being exposed to overweight/obese people at home or in school is associated with misperception. We hypothesized that misperception would be more common among overweight and obese youth and that misperception would be greater among those exposed to overweight/obesity at home and in school.

METHOD

The Québec Child and Adolescent Health and Social (QCAHS) Survey was a provincially representative, school-based survey of children and adolescents aged 9, 13, and 16 years, conducted between January and May 1999. The QCAHS

Survey was originally developed to assess the general health and social well-being of youth in Québec. Data were collected in age-specific, self-reported questionnaires for children and adolescents administered at school, and a self-reported parent questionnaire administered at home, which assessed family and social environment, parental education, and other socio-demographic information. Study procedures were approved by the ethics committees of the Direction Santé Québec of the Institut de la Statistique du Québec, the Ministère de l'Éducation du Québec, and Ste-Justine Hospital. A detailed description of the survey design and methodology has been previously published.(272) The final sample included 3665 children and adolescents (age 9, *n* = 1267; age 13, *n* = 1186; age 16, *n* = 1212) from 178 schools, with response proportions of 83, 79 and 78 percent for each age group, respectively.

Measures

Perceived weight status

Self-report of current weight status was assessed using the Stunkard Body Rating Scale,(282) a visual analogue scale consisting of seven sex-specific silhouettes of the same height, with weight ranging from underweight to obese. Participants selected the figure they perceived best corresponded to their current appearance.

Actual weight status

Anthropometric data, including measures of height and weight, were collected at school by ten teams of pediatric nurses, kinesiologists, and trained interviewers. Measurements were taken twice; a third measurement was taken if the first two differed by >0.5 cm for height or >0.2 kg for weight.(272) The average of the two closest measures was used for data analyses. Body mass index (BMI), calculated as weight/height^2 (kg/m^2), was used as the measure of actual weight status.

Weight status misperception

While the Stunkard Body Rating Scale is not directly matched to BMI percentiles, the silhouettes are highly correlated (r=0.7) with BMI percentiles.(283, 284) Therefore, to assess misperception of weight status, deviation of perceived weight status from the actual weight status was obtained in the following three-step approach:

2) Values from the seven-item visual analogue scale (Stunkard Body Rating Scale) of perceived weight status were assigned corresponding Z-score values (-3, -2, -1, 0, 1, 2, 3). Thus, the three middle silhouettes (-1, 0, 1) were thought to represent “normal” body weight. The remaining silhouettes were thought to represent the “overweight” and “underweight” categories, respectively.

2) BMI values were transformed into Z-scores using age- and sex-specific cutoffs of the 2000 Centers for Disease Control and Prevention (CDC) pediatric growth charts as a reference population.(285) The standardized BMI score indicates how many standard deviation units apart a child’s BMI is from the mean BMI of the reference group for their age and sex.

3) Weight status misperception was calculated as the arithmetic difference between the perceived weight *Z*-score and the BMI *Z*-score: [Misperception = $Z_{\text{Perceived weight}} - Z_{\text{BMI}}$].

A positive deviation unit for weight status misperception indicated an overestimation of weight status (i.e., participants perceived themselves to be heavier than their measured BMI). A negative deviation unit for weight status misperception indicated an underestimation of weight status (i.e., participants perceived themselves to be thinner than their measured BMI).

Exposure to overweight/obesity at home: Parent weight status

Self-report of height and weight was provided by the parent completing the questionnaire (78 percent of parent questionnaires were completed by mothers). BMI values were calculated as weight/height^2 (kg/m^2).

Exposure to overweight/obesity in school: Schoolmate weight status

Schoolmate weight status was calculated as the average BMI of all QCAHS Survey students attending the participant's school. Thus, an aggregate BMI was created for each school. On average, there were 20 students per school in 178 schools; ranging from 11 to 43 students per school. Average BMI for all students (N = 3591) was 20 kg/m^2 and this average BMI varied ±2 kg/m^2 between schools and ±3 kg/m^2 within schools.

Statistical Analysis

To test the hypothesis that overweight and obese participants would misperceive their weight status, compared with non-overweight youth, we computed an ANOVA test with follow-up comparisons. To test the hypothesis that exposure to obesity at home and in school is associated with greater misperception of weight status, we analyzed the data using multi-level linear regression modeling. This analytical approach was preferred as it permitted nested data (participant) within each school. Fixed effects (parent, schoolmate BMI) could be accounted for while simultaneously including a standard covariate (gender); and random effects (intercept) allowed for misperception to vary between schools. A total of 1049, 1170 and 1144 students of age 9, 13 and 16 from 69, 104 and 61 schools, respectively, had data on weight status misperception and were available for the analysis.

The effects of parent and schoolmate weight status were evaluated singularly and simultaneously, while controlling for gender, using three separate models. The base model, including gender and the random intercept, was created to adjust for the effect of gender. Second, parent BMI was added to the base model (Model 1). Third, schoolmate BMI was added to the base model (Model 2). Finally, to simultaneously test the effects of parent and schoolmate BMI, both were added to the base model (Model 3). These models were tested for each age group separately as the school-based sampling procedure, where 9, 13 and 16 year olds were derived from separate samples of schools, precluded using the entire dataset with age as a covariate due to multicollinearity between school and age variables. For all models, parent and schoolmate BMI were grand-mean centered to facilitate interpretation of the results. Centering a variable about its grand-mean yields an intercept that is interpreted as the estimate at the mean of a given variable, rather than at zero. Centering does not change the values or the significance levels of the estimated coefficients.(288) We present separate models by age.

RESULTS

Sample characteristics

The sample characteristics are presented in Table 7.1. Average BMI for 9, 13, and 16 year olds was 17.5, 20.6, and 22.2 kg/m^2, respectively. According to the CDC BMI growth charts, 14 percent of students were overweight (≥85th to <95th percentile), and 9 percent were obese (≥95th percentile). Average parent BMI was 25 kg/m^2 (SD = 4.6) and average schoolmate BMI was 20 kg/m^2 (SD = 4.3). These BMI values are consistent with those previously reported for adult and youth populations.(14, 316)

Misperception of weight status

The distribution of participants' perceived weight status on the Stunkard Body Rating scale by age and gender is presented in Table 7.2. Although 24 percent of children and adolescents were overweight or obese, only 1.6 percent perceived themselves as having excess weight, selecting overweight silhouettes (6 and 7). The overweight youth were significantly more likely to misperceive their weight (M = -1.19, SD = 0.67) compared to the non-overweight youth (M = -0.53, SD = 0.96, F = 214.25, p<0.001). Similar results were found for the obese youth (M = -1.27, SD = 0.78, F = 177.35, p<0.001). The distribution of the deviation units for weight status misperception by actual weight status (BMI) is presented in Table

7.3. For the total sample, 38.5 percent of the deviation units were one to three units below the mean, indicating that many youth underestimated their weight status (i.e., $Z_{\text{Perceived weight}}$ was one to three deviation units lower than Z_{BMI}). For non-overweight youth, 30.0 percent underestimated their BMI. In contrast, 71.4 percent of overweight and 59.4 percent of obese youth underestimated their weight status.

Exposure to overweight/obesity

There was significant variation between schools in weight status misperception (Table 7.4). Gender was significant for 13- and 16-year-olds (Table 7.4, base model). At age 13, boys overestimated their weight status (deviation units were more positive) compared with girls; in contrast, at age 16, girls overestimated their weight status. The effect of parent BMI was significant and negative for each age group (Table 7.4, Model 1). As parent BMI increased, participants' underestimated their weight status (deviation units were more negative). Schoolmate BMI was significant and negative for each age group (Table 7.4, Model 2). As schoolmate BMI increased, participants' underestimated their weight status (deviation units were more negative). Parent and schoolmate BMI remained significant and negative predictors of misperception for each age group, with the exception of parent BMI among 13-year-olds (Table 7.4, Model 3). For all three age groups, schoolmate BMI consistently had the strongest association with the misperception of weight status.

Post-hoc analyses

Post-hoc analyses included models with parent overweight status and percentage of overweight schoolmates. To control for potential confounding of the relationship between exposure to overweight/obesity and misperception by socioeconomic (SES) factors, our post-hoc analyses also included SES measures at both the student-level (household income, parental education) and school-level (an aggregate measure based on the percentage of mothers in a given school area without high school education), as well as interactions of the variables in the above models. The models with these covariates did not differ from the original models. The effects of SES at either the student- or the school-levels were not associated with the degree of misperception.

DISCUSSION

This study assessed whether children and adolescents' misperception of their weight status was associated with exposure to overweight/obesity at home and in school. In accordance with our first hypothesis, we found that many youth misperceived their weight status and the extent of this misperception was greater among overweight and obese children and adolescents. More specifically, overweight and obese youth were more likely to considerably underestimate their actual weight status compared to non-overweight youth. This finding is consistent with the previously reported literature.(251-254) The results also supported our second hypothesis such that youth exposed to overweight/obesity at home and in school, with higher parent and schoolmate BMI, were more likely to misperceive (underestimate) their weight status. This finding provides new information and extends the current literature regarding factors that influence misperception of weight status.

The mechanism underlying the role of exposure to overweight/obesity on misperception of weight status may differ across childhood and adolescence. Exposure to overweight/obesity both at home and in school appear to play an important role and exert independent effects on perception of weight status. As evident by the multi-level models with parent and schoolmate BMI entered singularly, children living with larger parents or attending school with larger schoolmates were more likely to underestimate their size. When both were entered into the model simultaneously, neither the direction nor the magnitude of the estimates changed, indicating that they both exerted independent effects. Interestingly, schoolmates' BMI exerted greater influence on weight status misperception than parent BMI.

It is possible that being exposed to overweight/obesity at home and in school plays a dynamic role in influencing misperception of weight status across development. The youngest children (9 years old) were particularly vulnerable to this influence both at home and in school. This is not surprising since the social milieu of children at this age is largely represented by their parents and schoolmates. Compared to the other age groups, 13 year olds were least vulnerable to the influence of home and school, and parents played a negligible role when considered simultaneously with the effects of schoolmates. This lack of effect of parents among 13-year-olds is not surprising. Some researchers have recently noted that parents seem to play a lesser role in influencing their children's behaviour during young adolescence, when peers and schoolmates may have a more influential role.(317, 318) Further, during later adolescence (16 years old), while there was a re-emergence of the effect of home and school, their influence was nonetheless not to the extent observed in the youngest children. It is possible that youth's perceptions are influenced by a broader social context including media as well as societal and cultural norms.

Misperception also differed by gender. It was not surprising that boys overestimated their weight status at age 13 while girls overestimated at age 16. It is possible that gender differences in the maturation process (i.e., puberty) largely contribute to these findings across the two age groups. Specifically, boys at age 13 overestimate their weight status because they may want to appear bigger and more mature; while, girls at age 16 overestimate their weight status because they may be more susceptible to cultural and societal pressures to be thin.

The key strength and contribution of this study is the unique conceptualization of weight status misperception. Previous research on misperception was limited to cross-tabulations of perceived weight status (e.g., about right, too heavy, too light) and BMI classification categories. Our misperception measure has the advantage of being a continuous measure of misperception and allowing for greater measurement precision. Further, our misperception measure is suitable for regression analyses to help researchers understand what factors are associated with weight status misperception. Second, the conceptualization of exposure to overweight/obesity using a multi-level framework with parent and schoolmate BMI was an important methodological strength as it exploited the nested structure of the data. Other strengths included the use of a representative population-based random sample and measured height and weight. Many previous studies relied on self-reported height and weight for BMI calculation to model the deviation between individuals' own perceptions of their weight status and BMI.(252, 319)

The first limitation of our study was the use of parents' self-report of height and weight. While self-reports provide only an estimate of actual, measured height and weight, research shows that adults closely approximate their height and weight, even though they are poor at identifying their weight status classification.(253) However, those who err tend to underestimate their height and weight;(252) and thus, parents' self-reports in this study provided a conservative estimate of their BMI. Second, although the measurement of schoolmate BMI was a strength of the study and served as a proxy for exposure to overweight/obesity in school, it was not feasible to assess the BMI of every schoolmate for each participant. Likewise, no measures of sibling, friends, or neighborhood BMI existed. Lastly, although we compared the strength of the associations across distinct age groups, it was not possible to evaluate the main effect of age due to the sampling strategy. We also could not assess ethnic variations in misperception in our study as our sample was predominantly French Canadian (78.9%).

Future research might also consider examining whether misperception is linked to parental recognition of their child's overweight status. Studies evaluating parental involvement in obesity prevention among children suggest that parents are better facilitators of behavior modification than children themselves and that both parents and children need to be ready for change.(314) Parents' recognition that their children's weight was in excess and presented a health risk was found to be key to parental readiness to encourage lifestyle changes in their children.(250) However, while more than 25 percent of Canadian children aged 2 to 17 are overweight or obese, only 9 percent of parents believe their child to be overweight or obese.(320)

Results of this study suggest that children and youth who are exposed to overweight/obesity in their immediate environments in which people they see on a daily basis, such as parents and schoolmates, are overweight or obese may develop inaccurate perceptions of what constitutes an appropriate weight status. Since familial (parents) and school (schoolmates) context influences children's perceptions of normal weight status, it becomes an important public health concern that youth's perceptions correspond to their actual body weight. It is also important that parents have an accurate perception of their child's body weight since parental awareness is key to behavioral change in children and adolescents.(250, 314, 320) Previous research has shown that one's weight status perception develops early in life, reportedly as early as age nine.(321, 322) Our finding that variation in misperception was attributable to schoolmate and parent BMI in children as young as age nine further highlights the need for obesity prevention early in the lifecourse. It is important that healthy lifestyles behaviors be adopted early in life when habits are being established and may be more malleable.

The prevalence of childhood obesity shows no signs of decline and prevention interventions to date have only limited success.(48, 50, 314) In order to improve the effectiveness of obesity prevention interventions, it may be prudent to help youth recognize they are at risk and correct their misperceptions. Incorporating misperception awareness as a component of obesity prevention interventions may prime youth to be more receptive to adopting healthy lifestyle behaviors.

TABLE 7.1. Sample characteristics by age, QCAHS Survey, Québec, Canada, 1999

	Age 9 (*n* = 1049)		**Age 13 (*n* = 1170)**		**Age 16 (*n* = 1144)**	
	M (%)	**SD (n)**	**M (%)**	**SD (n)**	**M (%)**	**SD (n)**
Girls	50.6	632	49.9	584	52.2	597
BMI, kg/m^2	17.5	3.4	20.6	4.1	22.2	3.9
Overweight[a]	14.1	176	13.8	162	13.8	158
Obese[b]	10.0	125	9.8	115	7.4	85
Weight status misperception, deviation units	0.4	1.1	0.9	0.8	0.7	0.7
Parent BMI, kg/m^2	24.7	4.9	24.7	4.5	24.7	4.4
Schoolmate BMI, kg/m^2	17.8	0.9	20.3	1.3	22.1	0.8
Education (parent), <H.S.	16.7	174	21.2	214	18.9	176
Education (spouse), <H.S.	23.6	209	26.3	222	27.6	215
Household Income, <$20,000	14.4	145	16.1	154	10.6	94
School socioeconomic status, mothers <H.S. per school	24.6	9	23.9	7	24.1	7

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; BMI, body mass index (kg/m^2); H.S., high school.

[a] Overweight: BMI ≥85th and <95th percentile value according to 2000 U.S. CDC growth charts.
[b] Obese: BMI ≥95th percentile value according to 2000 U.S. CDC growth charts.

TABLE 7.2. Proportion of boys and girls according to perceived weight status by age, QCAHS Survey, Québec, Canada, 1999

		Perceived weight status (%)						
	Age, years	1	2	3	4	5	6	7
Total		1.5	12.1	36.3	36.6	11.9	1.5	0.1
Boys	9	1.4	4.0	26.1	51.2	15.0	2.3	0.0
	13	1.7	15.0	41.2	27.4	13.4	1.2	0.2
	16	1.1	13.4	40.7	30.3	12.3	2.0	0.2
Girls	9	2.4	8.5	27.3	49.7	11.3	0.9	0.0
	13	1.7	19.5	43.3	26.8	7.8	0.9	0.0
	16	0.3	13.3	40.9	32.1	11.5	1.7	0.2

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey.

TABLE 7.3. Proportion of students according to weight status misperception, QCAHS Survey, Québec, Canada, 1999

	Underestimate weight[a] (%)			Overestimate weight[b] (%)		
	-3 to -2	**-2 to -1**	**-1 to 0**	**0 to +1**	**+1 to +2**	**+2 to +3**
Total	6.1	32.4	42.0	14.8	3.7	1.0
Non-overweight[c] (n = 2742)	3.8	26.2	45.1	18.8	4.8	1.3
Overweight[d] (n = 496)	14.1	57.3	28.4	0.2	0.0	0.0
Obese[e] (n = 325)	13.2	46.2	36.6	4.0	0.0	0.0

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; BMI, body mass index (kg/m^2).

[a] Underestimate weight: $Z_{\text{Perceived weight}}$ one to three deviation units lower than Z_{BMI}.
[b] Overestimate weight: $Z_{\text{Perceived weight}}$ one to three deviation units higher than Z_{BMI}.
[c] Non-overweight: BMI <85th percentile value according to 2000 U.S. CDC growth charts.
[d] Overweight: BMI ≥85th and <95th percentile value according to 2000 U.S. CDC growth charts.
[e] Obese: BMI ≥95th percentile value according to 2000 U.S. CDC growth chart.

TABLE 7.4. Multi-level models for exposure to obesity on weight status misperception by age, QCAHS Survey, Québec, Canada, 1999

		Age 9 (*n* = 1049)			Age 13 (*n* = 1170)			Age 16 (*n* = 1144)		
Model		**β**	**SE**	**p**	**β**	**SE**	**p**	**β**	**SE**	**p**
Base	*Fixed Effects*									
	Intercept	-0.40	0.044	<.0001	-0.94	0.033	<.0001	-0.74	0.029	<.0001
	Boy = 1	0.08	0.059	n/s	0.11	0.052	<.05	-0.13	0.049	<.01
	Random Effects									
	Between schools	0.07	0.023	--	0.03	0.014	--	0.02	0.01	--
	Within schools	1.21	0.05	--	0.66	0.028	--	0.54	0.023	--
	Fixed Effects									
1	Parent BMI	-0.04	0.007	<.0001	-0.01	0.006	<.05	-0.02	0.005	<.01
2	Schoolmate BMI	-0.27	0.033	<.0001	-0.06	0.022	<.001	-0.12	0.03	<.0001
3	Parent BMI	-0.04	0.007	<.0001	-0.01	0.006	n/s	-0.02	0.005	<.01
	Schoolmate BMI	-0.28	0.035	<.0001	-0.08	0.023	<.001	-0.11	0.035	<.001

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; BMI, body mass index (kg/m^2).

Model 3: Student-level: Weight Status Misperception = $\beta_{0i} + \beta_{1i}$ (Gender$_i$) + β_{2i} (Parent BMI$_i$) + ε_{0i}

School-level: $\beta_{0i} = \gamma_{00} + \gamma_{01}$ (Schoolmate BMI$_i$) + ζ_{0i}

$\beta_{1i} = \gamma_{10} + \gamma_{11}$ (Schoolmate BMI$_i$)

$\beta_{2i} = \gamma_{20}$

Chapter 8: Manuscript IV

When overweight youth misperceive their actual weight status and do not consider themselves to be overweight or obese, a fundamental impetus for long-term adherence to increased levels of participation in physical activity may be lacking. To follow-up on our hypothesis that misperception of weight status may be an important barrier to the success of prevention interventions targeting behaviour modification such as increased physical activity, in this fourth manuscript we assessed whether weight status misperception among youth is associated with level of participation in physical activity. Although previous studies hypothesized that acknowledging excess weight may motivate action and change, no study investigated if weight status misperception is related to levels of physical activity engaged in by youth.

TITLE: Youth who underestimate their weight status engage in less physical activity

SHORT TITLE: Weight misperception and physical activity

AUTHORS: Katerina Maximova, Jennifer O'Loughlin, Gilles Paradis, James A. Hanley, Marie Lambert, John Lynch

ABSTRACT

Objective: Improving physical activity in youth is potentially an important strategy for preventing obesity and its sequelae. However, engaging in healthy levels of physical activity requires substantial motivation. Although acknowledging excess weight may motivate action and change, no study has yet investigated if youth who do not recognize themselves as being overweight or obese are less likely to engage in physical activity.

Design: The Québec Child and Adolescent Health and Social Survey is a provincially representative, school-based survey of children and adolescents conducted between January and May 1999.

Subjects: 3665 children and adolescents (age 9, n = 1267; age 13; n = 1186; age 16; n = 1212) from 178 schools.

Measurements: Weight status misperception was calculated as the standardized difference between self-perceived weight status (Stunkard Body Rating Scale) and actual BMI (from measured height and weight). The number of physical activity sessions per week was the sum of 17 activities youth engaged in (outside their regular school physical education classes) during the previous 7 days.

Results: Sex-specific Poisson regression models indicated that girls who underestimated their weight status were less likely to engage in physical activity outside their regular gym class at school.

Conclusion: Misperception of overweight status may reduce motivation among youth to engage in healthy lifestyle behaviors such as physical activity, and may therefore hinder the success of obesity prevention interventions. Obesity prevention interventions that aim to encourage participation in physical activity among youth may need to incorporate components to address misperception of weight status.

KEYWORDS: physical activity; weight misperception; youth; obesity; Québec

BACKGROUND

Improving physical activity in youth is potentially a cost-effective strategy for preventing obesity and its sequelae.(181, 213) Yet the majority of youth do not meet recommended physical activity levels. Despite current recommendations for children and adolescents to accumulate at least 90 minutes of moderate-to-vigorous physical activity over the course of the day,(149) less than 10 percent of Canadian youth aged 5-19 years attain these current recommendations.(149, 150)

Long-term adherence to increased levels of physical activity is crucial to prevent weight gain (or regain) and higher BP in both adults and youth.(47, 51) However, most individuals relapse from adherence to high levels of physical activity, and adherence to a prescribed exercise regime remains a challenge. Although obesity prevention interventions can improve physical activity levels in non-clinical populations of youth,(181) the improvements were short-term and were not sustained in the long run.(49) Maintenance programs designed to help individuals sustain long-term improvements in physical activity have also had limited success.(247, 248)

Achieving and maintaining increases in physical activity levels is challenging and requires substantial motivation on the part of individuals to embrace lifestyle changes required to lose weight. A meta-analysis of 64 interventions aimed at preventing weight gain in children and adolescents found that an important factor consistently associated with larger effects was having participants self-select (volunteer) into the intervention.(49) These studies suggest that youth who have successfully maintained weight loss over the long term were highly motivated to do so a priori.

Accurately perceiving oneself as overweight or obese is considered an important cue for action and change, and has been linked to greater motivation to engage in healthy lifestyle behaviors.(249, 250) Both children and adults may need to perceive themselves to be at risk and recognize their overweight to be a health problem in order to change their lifestyle behaviors. Recognition of overweight on the part of individuals may be an important component of intervention strategies targeting behaviour modification such as increased physical activity and weight loss. However, growing evidence suggests that actual weight and perception of weight status often do not coincide. Significant proportions of individuals of all ages underestimate their weight status, and misperception is more common among overweight adults and youth.(251-254)

Misperception of overweight may be one explanation for the limited success of obesity prevention interventions aimed at modifying lifestyle behaviours. Theories of health behaviour change (c.f. Health Belief Model,(255) Transtheoretical Model of Behaviour Change,(256) Decisional Balance(257, 258)) have each emphasized the necessity of perceiving oneself "at risk" before behaviour change is possible. For obesity prevention, acknowledgement of excess weight has been hypothesized to improve motivation among youth and their parents to engage in healthy lifestyle behaviors.(249, 250) When overweight youth misperceive their actual weight status and do not consider themselves to be overweight or obese, a fundamental impetus for long-term adherence to increased levels of participation in physical activity may therefore be lacking. Although acknowledging excess weight may motivate action and change, no study has yet investigated if youth who do not recognize themselves as being overweight or obese are less likely to engage in physical activity. The objective of this study was to examine whether weight status misperception among youth is associated with the level of participation in physical activity.

METHODS

Study population

The Québec Child and Adolescent Health and Social (QCAHS) Survey was a provincially representative, school-based survey of children and adolescents aged 9, 13, and 16 years, conducted between January and May 1999. The QCAHS Survey was originally developed to assess the general health and social well-being of youth in Québec. Data were collected in age-specific, self-report questionnaires for children and adolescents administered at school, and a self-report parent questionnaire administered at home, which assessed the family and social environment, parental education, and other socio-demographic information. Study procedures were approved by the ethics committees of the Direction Santé Québec of the Institut de la Statistique du Québec, the Ministère de l'Éducation du Québec, and Ste-Justine Hospital. A detailed description of the survey design and methodology has been previously published.(272) A total of 1267 children aged 9 years, and 1186 and 1212 adolescents aged 13 and 16 years, respectively, from 178 schools participated in the study and were available for analysis. The response proportions were 83, 79 and 78 percent in each age group.

Measures

Physical activity

Students completed a 7-day recall checklist that asked them to report for each day of the preceding week (Monday to Sunday) each physical activity they had engaged in for at least 15 minutes without interruption. The checklist was adapted from the Weekly Activity Checklist (274)to reflect common activities engaged in by children and adolescents in Québec. The original instrument correlated with accelerometer-measured physical activity in youth ($r=0.34$, $p<0.01$) and its 3-day test-retest reliability was $r=0.74$.(275) The number of physical activity sessions per week was the sum of 17 activities youth engaged in outside their regular physical education classes at school during the previous 7 days.

Misperception of weight status

Misperception of weight status was the deviation of the actual relative weight status from perceived weight status.(323) Actual weight status was based on body mass index (BMI) obtained from measured height and weight (weight/height^2 (kg/m^2)). Perceived weight status was based on self-report of current weight status using the Stunkard Body Rating Scale,(282) a visual analogue scale consisting of seven sex-specific silhouettes of the same height, with weight ranging from underweight to obese. The deviation unit for weight status misperception was the arithmetic difference between z-transformed BMI, using age-and sex-specific cutoffs obtained from the 2000 CDC pediatric growth charts,(285) and z-transformed perceived weight [Misperception = $Z_{\text{Perceived weight}} - Z_{\text{BMI}}$].(323) Thus, a deviation unit greater than zero identified students who underestimated their actual weight (i.e., participants who indicated they perceived themselves to be heavier than their measured BMI); a deviation unit less than zero identified students who overestimated their actual weight status (i.e., participants who indicated they perceived themselves to be thinner than their measured BMI).

Statistical Analysis

The hypothesis that youth who underestimate their weight status engage in fewer physical activity sessions per week than those who do not underestimate their weight status was tested using sex-specific Poisson regression models fitted to QCAHS Survey data. In order to take the loss of precision resulting from the stratified, cluster sampling design of the QCAHS Survey into account, I used design effects were defined as a ratio of the variance under the current design to the variance that would have been obtained under simple random sampling.(272) The model included weight status misperception; student's age (9 years (reference category), 13 years, and 16 years); parental BMI (self- report of height and weight by the parent completing the questionnaire; computed as weight/height^2 (kg/m^2)); parental education (summary index of education categories (primary school, high school, vocational or trade school, college/CEGEP, university) reported by the parent completing the questionnaire for both spouses); and annual household income (categories of $10,000 increments self-reported by the parent completing the questionnaire were square root transformed to reflect the non-linear relationship between income and health). A total of 1758 boys and 1828 girls with complete data on physical activity and weight status misperception were available for analysis.

RESULTS

Boys and girls aged 13 or 16 years were more likely to underestimate their weight status, compared with boys and girls aged 9 years. The average deviation unit for weight status misperception in 9, 13, and 16 year-old boys was 0.4, 0.9, and 0.8 units (Table 8.1). The average deviation unit for weight status misperception in same-aged girls was 0.4, 1.0, and 0.7 units. Between 30 and 52 percent of boys and girls aged 9, 13, and 16 years underestimated their weight status (i.e., $Z_{\text{Perceived weight}}$ was one to three deviations lower than Z_{BMI}). The number of physical activity sessions per week declined with age and was lowest in 16 year-old boys and girls (Table 8.1). However, boys in all three aged groups engaged in greater number of physical activity sessions per week than girls. The majority of youth engaged in low levels of physical activity (Figures 8.1.1 and 8.1.2). Nearly 60 percent of boys and 70 percent of girls engaged in 7 or fewer physical activity sessions per week.

Misperception of weight status was negatively associated with the number of physical activity sessions per week in boys and girls such that the more they underestimated their weight status (i.e., $Z_{\text{Perceived weight}}$ was lower than Z_{BMI}), the less they engaged in physical activity outside their regular gym class at school

(Table 8.2). After adjusting for student's age and other covariates, the association was significant in girls but not in boys. For every deviation unit of weight status misperception, girls engaged in 0.6 fewer physical activity sessions per week.

DISCUSSION

In this study we found that youth who underestimated their weight status were less likely to engage in physical activity outside their regular gym class at school. The association was significant in girls but not in boys, after adjusting for student's age and other covariates. Previous studies reported that most youth underestimate their actual weight, and that the extent of this misperception is greater among overweight children and youth.(251-254, 323) Among Québec youth, we have previously reported that 38.5 percent of youth aged 9, 13, and 16 years underestimated their weight status, and these proportions were 71.4 and 59.4 percent among overweight and obese youth, respectively.(323) The results of this current analysis extend the emerging literature on factors associated with weight status misperception in youth. In this study, we investigated the association between misperception of weight status and physical activity.

Results of this study provide empirical evidence that misperception of overweight is associated with the level of participation in physical activity in youth, providing support to theories of health behaviour change which postulate that a crucial step in the behaviour modification process is acknowledgement of "being at risk."(255, 257, 258) Indeed, Canadian clinical practice guidelines on the prevention and management of obesity in children and adults recommend that clinicians assess readiness and barriers to change, prior to implementing a healthy lifestyle plan for weight control or management.(47) A recent application of the Transtheoretical Model demonstrated that the majority of children and adolescents were not ready for an obesity prevention intervention.(261) Although they were not participating in healthy lifestyle behaviors and did not meet national recommendations for physical activity, or for fruit and vegetable consumption, most did not realize they needed to adopt these healthy behaviors.

Results of our analysis support the notion that healthy lifestyle behavior changes may be more likely to occur if youth recognize themselves as overweight or obese. Addressing weight status misperception among youth so that their perceptions correspond to actual weight status may therefore be an important component of obesity prevention interventions. Youth who are exposed to overweight and obesity in their immediate environments in which people they see on a daily basis such as parents and schoolmates, are overweight or obese may develop inaccurate perceptions of what constitutes an appropriate weight status and have been shown to be more likely to underestimate their weight status.(323) Helping youth correct perceptions of weight status may require targeting family, school and other environments.

A strength of this study is its conceptualization of weight status misperception.(323) Previous measures of misperception were derived by cross-tabulating perceived weight with actual weight categories. In contrast, the continuous nature of our misperception measure permitted investigation of factors associated with misperception. This study was based on a large representative population-based random sample of Québec youth. Moreover, while previous studies used self-reported height and weight, the measure of weight status misperception in this analysis was based on height and weight measured according to standardized measurement protocols. However, because the QCAHS Survey data are cross-sectional, causal inferences of the association between physical activity and weight status misperception should be made with caution.

The more girls underestimated their weight status, the less likely they were to engage in physical activity outside their regular gym class at school. Misperception of overweight status may reduce motivation among youth to engage in healthy lifestyle behaviors such as physical activity, and may therefore hinder the success of obesity prevention interventions. Obesity prevention interventions that aim to encourage participation in physical activity among youth may need to incorporate components to address misperception of weight status.

TABLE 8.1. Sample characteristics of boys and girls by age, QCAHS Survey, Québec, Canada, 1999

	Boys						Girls					
	9 years old (n = 623)		13 years old (n = 585)		16 years old (n = 550)		9 years old (n = 639)		13 years old (n = 587)		16 years old (n = 602)	
	Mean (%)	SD (n)	Mean (%)	SD (n)	Mean (%)	SD (n)	Mean (%)	SD (n)	Mean (%)	SD (n)	Mean (%)	SD (n)
Physical activity, No./week	7.3	5.6	8.0	6.1	7.1	5.2	6.4	5.2	6.3	5.3	5.1	4.6
BMI, kg/m^2	17.5	3.3	20.4	3.8	22.3	3.8	17.5	3.5	20.7	4.3	22.0	4.0
Overweight[a]	(14.3)	(89)	(14.3)	(85)	(12.5)	(69)	(13.9)	(88)	(13.3)	(78)	(14.8)	(89)
Obese[b]	(10.9)	(68)	(10.8)	(64)	(9.6)	(53)	(9.2)	(58)	(9. 0)	(53)	(5.5)	(33)
Weight status misperception, deviation units	-0.4	1.1	-0.9	0.8	-0.8	0.9	-0.4	1.2	-1.0	0.8	-0.7	0.6
Underestimate weight[c]	(29.3)	(167)	(44.9)	(246)	(43.4)	(225)	(29.5)	(179)	(52.2)	(295)	(30.5)	(180)
Parent BMI, kg/m^2	24.8	4.9	24.9	4.7	24.8	4.2	24.4	4.9	24.5	4.4	24.6	4.6
Education (parent), <H.S.	(16.0)	(83)	(21.6)	(108)	(19.1)	(84)	(17.8)	(95)	(21.)	(109)	(19.)	(95)
Education (spouse), <H.S.	(24.1)	(106)	(27.5)	(114)	(29. 0)	(108)	(23.)	(105)	(24.8)	(108)	(26.4)	(109)
Household income, <$20,000	(14.6)	(74)	(16.5)	(78)	(9.2)	(39)	(14.5)	(74)	(15.9)	(78)	(12.2)	(57)

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; SD, standard deviation; BMI, Body Mass Index (kg/m^2); H.S., high school.

[a] BMI ≥85th and <95th percentile value according to 2000 U.S. CDC growth charts.

[b] BMI ≥95th percentile value according to 2000 U.S. CDC growth charts.

[c] $Z_{\text{Perceived weight}}$ one to three deviation units lower than Z_{BMI}.

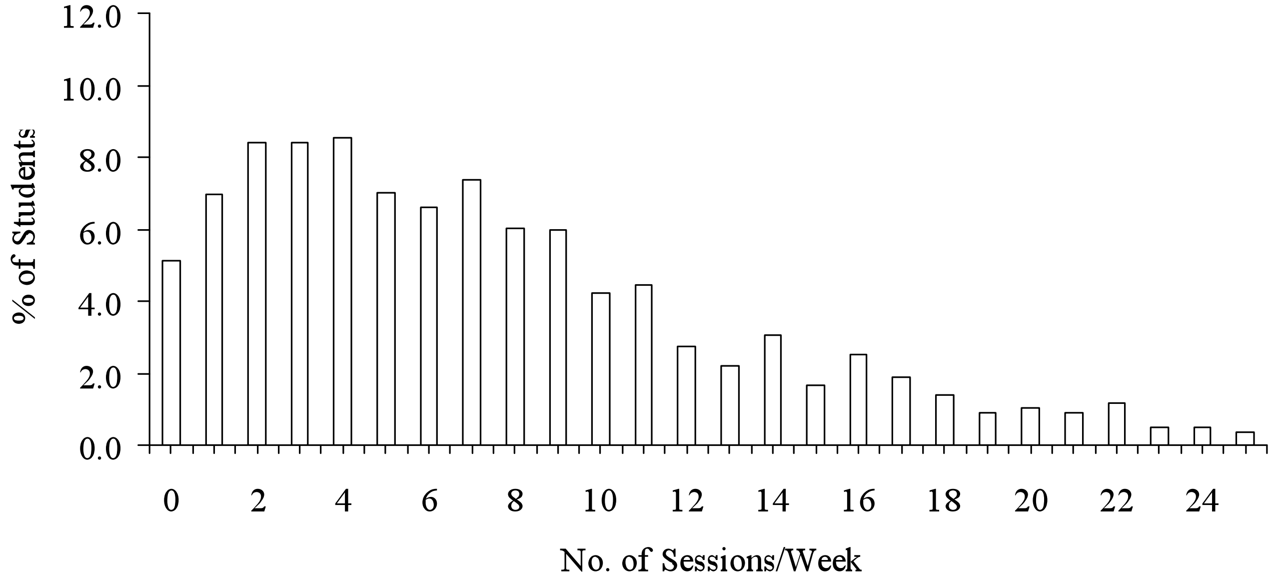

FIGURE 8.1.1. Proportion of boys according to number of physical activity sessions engaged in per week, QCAHS Survey, Québec, Canada, 1999

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; No., number.

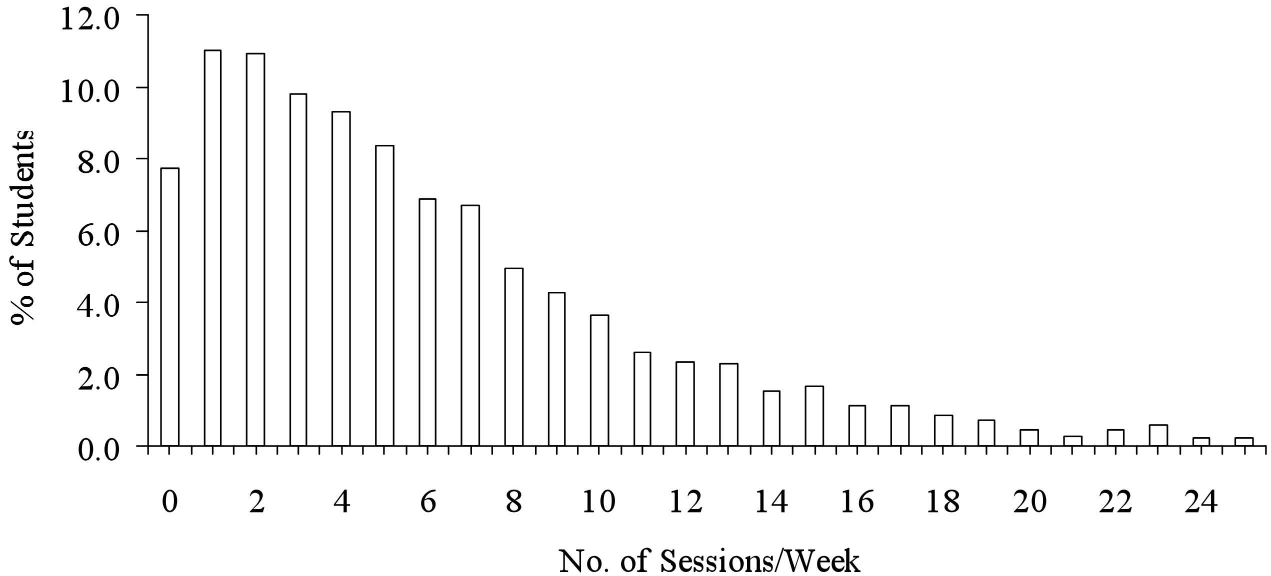

FIGURE 8.1.2. Proportion of girls according to number of physical activity sessions engaged in per week, QCAHS Survey, Québec, Canada, 1999

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; No., number.

TABLE 8.2. Estimates of the effect of weight status misperception and covariates on the number of physical activity sessions per week in boys and girls, QCAHS Survey, Québec, Canada, 1999

	Boys (n=1275)		**Girls (n=1373)**	
	Coeff	**95% CI**	**Coeff**	**95% CI**
Weight status misperception, deviation units	-0.1	(-0.43, 0.28)	-0.6	(-0.91, -0.29)
Age = 13 years	-0.2	(-1.11, 0.68)	-0.5	(-1.30, 0.29)
Age = 16 years	-0.8	(-1.70, 0.03)	-1.6	(-2.36, -0.75)
Parent BMI, kg/m^2	0.0	(-0.10, 0.04)	0.0	(-0.08, 0.03)
Parental education	0.0	(-0.11, 0.19)	0.1	(-0.03, 0.24)
Household income	0.0	(-0.01, 0.00)	0.0	(-0.00, 0.01)
Intercept	7.4	(4.80, 9.99)	5.0	(2.84, 7.22)

Abbreviations: QCAHS, Québec Child and Adolescent Health and Social Survey; CI, confidence interval; BMI, Body Mass Index (kg/m^2).

Chapter 9: Summary and conclusion

The atherosclerotic process which leads to CVD begins in childhood. Elevated BP is one of the most important risk factors for the development of atherosclerosis and CVD later in life. Since elevated BP during childhood and adolescence tracks to adulthood, early interventions to prevent increases in BP are needed. Intervention strategies to prevent declines in physical activity and excess weight gain during adolescence may prevent increases in BP and have the potential to reduce the CVD burden associated with elevated BP. Despite the need for effective interventions, our knowledge base in this area remains limited and under-developed. Interventions to improve physical activity levels to prevent excess weight gain and elevated BP in youth have had limited success, and there is a need for research aimed at improving our capacity for developing effective prevention.

Childhood and adolescence are critical periods for the development of chronic disease risk factors which contribute to the progression of atherosclerosis.(324) Adolescence in particular is a period of rapid growth when BP, height, weight and body fat increase rapidly. Yet it is characterized by sharp declines in physical activity levels.(56, 57) In this thesis, I examined how the declines in physical activity and the gains in weight or body fat that occur during adolescence affect BP in youth. In addition, I assessed misperception of weight status as a possible barrier to the success of intervention strategies to prevent declines in physical activity and excess weight gain in youth. The four research objectives presented in this thesis are interconnected to achieve this overall goal. I began by providing an overview of the literature on BP development in youth and the role of physical inactivity and excess weight on BP in youth, and identified methodological challenges in studying these associations. I also identified areas needing further investigation in order to improve our understanding of why obesity prevention intervention may have had limited success to date.

In the first manuscript, we found that boys and girls had similar SBP levels at age 12 years. However, sex differences in SBP increases with age apparently emerged thereafter. SBP increased rapidly in boys until age 17 years. In contrast, SBP increased only modestly in girls. Although BP increases with age during adolescence represent normal human biology, they can be excessive among adolescents living in industrialized Western societies as a result of physical inactivity and unhealthy levels of caloric intake that lead to increased body weight. While previous studies in this domain highlighted sex differences in the patterns of BP increases during adolescence, few have considered the effect of contemporaneous changes in weight or body fat. It remains unclear whether sex differences in BP increases with age during adolescence are due to differences between boys and girls in gains in body size, adiposity, hormones, or other factors.(134)

The results of the first manuscript demonstrated that despite differences in the patterns of SBP increases with age between boys and girls, no significant sex differences were observed in the association of changes in BMI, waist circumference, and triceps and subscapular skinfold thickness with SBP change over five years. An increase in one BMI unit, one cm waist circumference, or one mm triceps and subscapular skinfold thickness was associated 0.7 mmHg, 0.24 mmHg, 0.3 and 0.4 mmHg SBP increase. The results of the first manuscript help provide basic knowledge on the natural history of BP changes during adolescence and also provide information on how changes in weight and body fat relate to BP in adolescence. The results underscore that the effect of weight gain during adolescence is equally detrimental in terms of BP increases with age in boys and girls. We also found that SBP levels varied substantially between students at age 12 years but the rates of change in SBP with age did not, indicating that the course of SBP increases may be set before age 12 years. This finding is important and highlights the need for early interventions before age 12 years to prevent excess weight gain in youth.

High intra-individual variability in BP, which leads to a misclassification of a student's "true" BP level, poses methodological challenges to analyzing BP change over time in youth since it is difficult to assess whether BP variance is attributable to "true" variation in BP levels or random error. Few studies have examined patterns of BP change over time and its determinants in adolescence employing analytical techniques that adjust for intra-individual variability in BP. Individual growth modeling used to analyze repeated SBP assessments in the first manuscript improves the precision of parameter estimates of BP change over time, and breaks up the term for random error variation by estimating statistical terms for within- and between-individual variance components to help estimate “true” variation.(140) The analysis in the first manuscript is one of the few longitudinal studies that applied individual growth modeling to the study of BP change over time.

We also used several indicators of adiposity when assessing the association between changes in weight and SBP increases. We found that different indicators of adiposity (BMI, waist circumference, and skinfold thickness) had similar effects on changes in SBP, indicating that different measures of adiposity seem to equally capture the deleterious effect of weight gain on SBP in adolescents. Although waist circumference has been recently advocated as a better indicator of adiposity and a more important predictor of BP and cardiovascular risk in youth than BMI, the measure of waist circumference provided no additional information over and above BMI to predict changes in BP with age in this analysis.

In the second manuscript, we investigated the relationship between the declines in physical activity and SBP. We found that the declines in physical activity during adolescence were inversely associated with SBP in youth, independent of changes in adiposity. A decline of one MVPA session per week with each year of age was associated with 0.29 and 0.19 mmHg higher SBP in girls and boys in early adolescence (12.8 to 15.1 years old), and 0.40 and 0.18 mmHg higher SBP in late adolescence (15.2 to 17.0 years old). These associations were not attenuated by contemporaneous changes in adiposity in girls during late adolescence. Although weaker, these associations were evident in boys during late adolescence as well as in both girls and boys during early adolescence.

The large number of repeated assessments of physical activity facilitated modeling of longitudinal patterns of physical activity in early and late adolescence using individual growth models, such that I derived estimates of initial level and rate of decline in physical activity for each student. There were no measures of puberty in the NDIT Study, yet the association between physical activity and SBP may be confounded by pubertal maturation. We attempted to mitigate this limitation in part by using an innovative study design that divided the follow-up into two periods corresponding to early (mean age 12.8 to 15.1 years) and late adolescence (mean age 15.2 to 17.0 years) on the premise that the second period may be less confounded by pubertal maturation, particularly in girls. A major strength of this study design is that it allowed estimation of the longitudinal patterns of physical activity in early and late adolescence, which preceded SBP measurement at the end of each period, and may therefore allow for stronger claims about the causal relations between physical activity and SBP in youth.

Since lifestyle behaviours that determine BP levels during adolescence are established at least in part early in life and may track into adulthood, these results add to the field of epidemiology by increasing our understanding of the role of physical inactivity and weight gain in the development of BP in youth. They highlight the importance of preventing declines in physical activity during adolescence in order to prevent part of the BP increases observed in youth.

Despite the knowledge that weight gain and physical inactivity are detrimental for SBP in youth, prevention interventions in general populations of youth have had limited success. Although several interventions improved physical activity levels in general populations of youth,(181) these improvements were often short-term and were not sustained in the long run. While long-term adherence to increased levels of physical activity is crucial to prevent weight gain (or regain) and higher BP,(47, 51) achieving and maintaining increased physical activity levels is challenging and requires substantial motivation. In the third and fourth manuscripts, we hypothesized that recognition on the part of the young people that their weight status exceeds normal weight and poses a health risk is crucial for behavior change, and that this lack of recognition may be an important barrier to the success of prevention interventions targeting behaviour modification such as increased physical activity.

In the third manuscript, we examined the discrepancy between youth's actual weight status and their perceptions of their weight and found that many youth misperceived their weight status. Overweight and obese youth were more likely to underestimate their weight compared to non-overweight youth. More specifically, the analysis showed that many overweight youth did not see themselves as having excess weight. While previous studies have reported that perceptions among youth of their weight status differed from their actual weight, we were the first to identify factors associated with weight status misperception. We hypothesized that living in an obesogenic environment may be associated with the degree of misperception. We found that the weights of parents and peers at school were important such that the heavier the parents and peers, the more likely youth were to underestimate their weight. Results of this study suggest that youth who are exposed to overweight/obesity in their immediate social environments in which people they see on a daily basis, such as parents and schoolmates, are overweight or obese may develop inaccurate perceptions of what constitutes an appropriate weight such that their own overweight may seem normal by comparison. Our finding that, compared to the other age groups, the youngest children (age 9 years) were particularly vulnerable to the influence of exposure to overweight and obesity at home and in school, highlights again the need for obesity prevention early in the lifecourse. Incorporating healthy weight awareness as a component of obesity prevention interventions may prime youth to be more receptive to adopting healthy lifestyle behaviors.

In the fourth manuscript, we investigated whether recognition of one's own overweight status is associated with the levels of physical activity youth engage in. We found that youth who underestimated their weight status were less likely to engage in physical activity. When overweight children and adolescents misperceive their actual weight status and do not consider themselves to be overweight or obese, a fundamental impetus for long-term adherence to increased levels of participation in physical activity may be lacking. Results of this analysis extend the emerging literature on factors associated with weight status misperception in youth, and provide empirical evidence that misperception of overweight is associated with the level of participation in physical activity in youth. Results of this study support the notion that misperception of overweight status may reduce motivation among youth to engage in physical activity, and may therefore hinder the success of obesity prevention interventions. They suggest that youth may be less likely to heed public health messages about the risks of obesity or be receptive to obesity prevention interventions that require lifestyle behavior modifications if they misperceive their weight status.

Unlike measures used in previous studies, the misperception measure was used as a continuous measure of misperception in regression analysis, allowing for greater measurement precision. Further, constructing measures at both the individual and aggregate (school) level to assess exposure to overweight/obesity in multi-level regression models that were applied to cross-sectional QCAHS Survey data in the third manuscript was also a novel contribution to the literature in this domain.

Taken together, the results of the third and fourth manuscripts support the recommendation of the Canadian clinical practice guidelines on the prevention and management of obesity in children and adults that clinicians assess readiness and barriers to change prior to implementing a healthy lifestyle plan for weight control or management.(47) Obesity prevention interventions that aim to encourage participation in physical activity among youth may need to address misperception of weight status to help youth recognize that they are at risk. However, correcting perceptions among youth may require targeting family, school and other environments.

Results of these two analyses also support advocating for monitoring changes in BMI or other indicators of adiposity during childhood and adolescence.(325, 326) Although there is opposition to regular weight checks of youth in schools because it may stigmatize overweight or obese youth,(327-329) our results suggest that it is important to monitor weight status in youth using objective measures of weight status, rather that rely on youth's perceptions that their weight is in excess and poses a health risk.

Limitations

BP was measured only on three occasions in the NDIT Study (1999/2000, 2002, 2004). Modeling longitudinal changes in SBP with three data points for the first analysis required the assumption that BP increases linearly with age. Although the inclusion of quadratic and cubic terms may be more appropriate for modeling BP changes in youth (to reflect the increases in BP with age during adolescence), it was not possible to do so with the NDIT data. However, adolescents in the NDIT Study cohort were, on average, between 12 and 17 years old during the 5 years of follow-up, and previous studies on the longitudinal trajectories of SBP show linear increases with age during this period.(131) In the NDIT Study, BP was assessed on three occasions with unequal time intervals between data collection waves. The difference between the first and second BP data collection occasions was about 3 years (waves 1 to 12), and the difference between the second and third data collection occasions was about 2 years (waves 12 to 19). We used students' age to represent the passage of time in individual growth models in an attempt to mitigate, at least in part, the issue of unequally spaced data points. The number of BP measurements per student also varied. While individual growth models can be fit to unbalanced data, it requires the assumption that data were missing “at random”.(140)

The measures of physical activity in both the NDIT Study and QCAHS Survey were based on self-report in a physical activity recall checklist which did not include information on either the duration or the intensity of these activities. The amount and type of physical activity needed to prevent weight gain and BP increases, as well as to confer other health benefits in youth are currently not well understood.(213) Having this information would have allowed quantification of the relationship between the declines in physical activity during adolescence and BP more precisely. A serious limitation in the NDIT Study was the lack of a measure of puberty. We attempted to mitigate this limitation by using changes in height as a crude proxy for the maturation process in both the first and second analyses, and also by using an innovative study design in the second analysis. Nonetheless, having access to provincially representative cross-sectional data, as well as longitudinal cohort data that were already available superseded these limitations. It would not have been possible in the context of this doctoral dissertation to collect the same high quality data with a large number of participants that were either provincially representative or were assessed repeatedly over 5 years, using the same high quality standardized measurement protocols for BP and anthropometry.

Conclusion

Collectively, the results of the four manuscripts presented in this thesis underscore the need for CVD prevention beginning early in life. In the context of CVD prevention, results of this thesis support preventive strategies to protect youth from increasing physical inactivity and excess weight gain, which could lead to higher BP. The progression of atherosclerosis and its sequelae, such as coronary/ischemic heart disease, congestive heart failure and stroke, can be prevented through fostering and maintaining healthy behaviour patterns during childhood and adolescence. The first and second manuscripts show that weight gain and declines in physical activity during adolescence have a detrimental effect on BP in youth, highlighting the need for effective interventions at the population level to prevent excess weight gain and declines in physical activity before age 12 years. The increasing prevalence of childhood obesity adds to the urgency of the problem and the need for such prevention.

Results of this thesis support the Canadian Heart Health Strategy and Action Plan, a recent initiative by the Government of Canada which aims to reduce heart disease by persuading Canadians to live healthier lifestyles.(330) The goals of this initiative include having 35 percent fewer obese children by 2015. The series of analyses presented in this thesis underscore the need to extend and focus such initiatives on children and adolescents, yet also caution against investing in costly prevention interventions without considering individual readiness to adopt lifestyle changes. This is because in the third manuscript we have shown that youth often do not judge their weight status accurately, particularly when they live in obesogenic environments.

Health promotion programs that aim to prevent excess weight gain and physical inactivity in youth may need to incorporate a component to increase awareness of weight status misperception in order to help youth and their parents understand what constitutes a healthy weight and whether their own weight is within healthy norms. In the fourth manuscript we have shown that youth who do not perceive their weight status accurately are less likely to engage in physical activity. Weight status misperception may then play a role in the limited success of obesity prevention interventions such that if overweight or obese youth do not perceive their weight to be a problem or a health risk, they may be less motivated to engage in healthy levels of physical activity and, more importantly, to sustain these levels over time.

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Appendices

Appendix 1. Nicotine Dependence in Teens Study questionnaire

PLEASE PRINT YOUR NAME ______________________________

First name Last name

- -

MCGILL UNIVERSITY STUDY ON NICOTINE DEPENDENCE IN TEENS

QUESTIONNAIRE VERSION	0	6		
SCHOOL				
DOSSIER NUMBER				
SURVEY NUMBER				
TODAY'S DATE	DAY	MONTH	YEAR	
GRADE				
RECALL MONTHS	0	2		

1. In what month is your birthday?

- ☐ 1 January
- ☐ 2 February
- ☐ 3 March
- ☐ 4 April
- ☐ 5 May
- ☐ 6 June
- ☐ 7 July
- ☐ 8 August
- ☐ 9 September
- ☐ 10 October
- ☐ 11 November
- ☐ 12 December

2. On what day of the month is your birthday? Circle the correct day.

1 2 3 4 5 6 7 8 9 10

11 12 13 14 15 16 17 18 19 20

21 22 23 24 25 26 27 28 29 30 31

3. In what year were you born?

- ☐ 1984
- ☐ 1985
- ☐ 1986
- ☐ 1987
- ☐ 1988
- ☐ Other ______________________________
  Specify year

6. This chart asks about: (1) the adults with whom you live, and (2) whether or not the adults you live with currently smoke cigarettes.

First, check the box if you live with the person. Next, <u>for the people you live with</u>, check the box if he/she currently smokes cigarettes. If you live in more than one household (part-time with your Mom and part-time with your Dad), check ALL the boxes that apply…

Check the box if …	You live with this person	He/she currently smokes cigarettes
Biologic mother	☐	☐
Biologic father	☐	☐
Step-mother	☐	☐
Step-father	☐	☐
Aunt(s)	☐	☐
Uncle(s)	☐	☐
Grandmother(s)	☐	☐
Grandfather(s)	☐	☐
Other(s) → Name them	☐	☐
a) ______________________	☐	☐
b) ______________________	☐	☐

7. Please write the correct numbers in the boxes. <u>If an answer is zero, please write "0".</u>

→ How many *brothers, step-brothers and half-brothers* do you have? ☐

→ How many *sisters, step-sisters, and half- sisters* do you have? ☐

→ How many of your *brothers, step-brothers, and half-brothers* smoke cigarettes? ☐

→ How many of your *sisters, step-sisters, and half-sisters* smoke cigarettes? ☐

8. Now, think about your friends. How many of the people whom you usually hang out with smoke cigarettes?

- ☐ 1 None
- ☐ 2 A few
- ☐ 3 About half
- ☐ 4 More than half
- ☐ 5 Most or all

15. **Now, think about the physical activities that you did last week from Monday to Sunday <u>outside</u> your regular school gym class. For each activity that you did <u>for 5 minutes or more at one time</u>, mark an "X" to show the day(s) on which you did that activity.**

	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.	Sun.
Bicycling to school, bicycling to do errands, going for a bicycle ride							
Swimming/diving							
Basketball							
Baseball/softball							
Football							
Soccer							
Volleyball							
Racket Sports (badminton, tennis)							
Ice hockey/ball hockey							
Jump rope							
Downhill skiing, snowboarding							
Cross-country skiing							
Ice skating							
Rollerblading, skateboarding							
Gymnastics (bars, beams, tumbling, trampoline)							
Exercise / physical conditioning (push-ups, sit-ups, jumping jacks, weight-lifting, exercise machines)							
Ball-playing (dodge ball, kickball, wall-ball, catch)							
Track and field							
Games (chase, tag, hopscotch)							
Jazz/classical ballet							
Dancing (aerobic, folk, at a party)							
Outdoor play (climbing trees, hide and seek)							
Karate/ Judo/ Tai Chi/ Kung Fu							
Boxing, wrestling							
Outdoor chores (mowing, raking, gardening)							
Indoor chores (mopping, vacuuming, sweeping)							
Mixed walking / running / jogging							
Walking							
Running/Jogging							
Other(s) → Name them							
a)							
b)							
c)							

16. **<u>Since September of this school year</u>, did you belong to any of the following intramural or extramural school sports teams (teams that were not part of your regular gym class)…?**

	Yes
School basketball team	☐
School soccer team	☐
School football team	☐
School track and field team	☐
School rugby team	☐
School wrestling team	☐
School swimming team	☐
School softball team	☐
School cross-country ski team	☐
School volleyball team	☐
School gymnastics team	☐
School hockey team	☐
Other(s) → Name them a) ________________ b) ________________	

17. Now think about sports teams and lessons <u>outside of school</u>. <u>In the past 3 months</u>, did you belong to a…?

	Yes
Basketball team	☐
Soccer team	☐
Football team	☐
Swimming team	☐
Baseball team	☐
Volleyball team	☐
Hockey team	☐
Ballet/dance classes	☐
Aerobics classes	☐
Ski lessons	☐
Judo/Karate lessons	☐
Other(s) → Name them	
a) ______________________	
b) ______________________	

18. How many hours of television (including video movies) do you usually watch in a single day? ***If the answer is zero, write "0" in the box. If the answer is less than ½ hour, write "LT ½".***

On weekdays, I usually watch [ ] hour(s) of television a day

On weekends, I usually watch [ ] hour(s) of television a day

19. How many hours do you usually play video or computer games, or use the Internet in a single day? ***If the answer is zero, write "0" in the box. If the answer is less than ½ hour, write "LT ½".***

On weekdays, I usually play video or computer games …. [ ] hour(s) a day

On weekends, I usually play video or computer games …. [ ] hour(s) a day

20. During the past 3 months, how often have you…?

	Never	Rarely	Sometimes	Often
Felt too tired to do things	☐ 1	☐ 2	☐ 3	☐ 4
Had trouble going to sleep or staying asleep	☐ 1	☐ 2	☐ 3	☐ 4
Felt unhappy, sad, or depressed	☐ 1	☐ 2	☐ 3	☐ 4
Felt hopeless about the future	☐ 1	☐ 2	☐ 3	☐ 4
Felt nervous or tense	☐ 1	☐ 2	☐ 3	☐ 4
Worried too much about things	☐ 1	☐ 2	☐ 3	☐ 4

21. During the <u>past 3 months</u>, have you been worried or stressed by any of the following…?

	Not at all OR This does not apply to me	A little bit	Quite a bit	A whole lot
Your parents separating or divorcing	☐1	☐2	☐3	☐4
Loneliness	☐1	☐2	☐3	☐4
Breaking up with your boyfriend or girlfriend	☐1	☐2	☐3	☐4
Your relationship with your father	☐1	☐2	☐3	☐4
Your relationship with your mother	☐1	☐2	☐3	☐4
Your relationship with your brother(s)/ sister(s)	☐1	☐2	☐3	☐4
Your relationship with your friends	☐1	☐2	☐3	☐4
A health problem (such as acne or asthma)	☐1	☐2	☐3	☐4
Your weight	☐1	☐2	☐3	☐4
Sex	☐1	☐2	☐3	☐4
Your new family (parents remarried)	☐1	☐2	☐3	☐4
Financial problems in your family	☐1	☐2	☐3	☐4
School work	☐1	☐2	☐3	☐4
Other(s) → Please describe				
a) ______________________________	☐1	☐2	☐3	☐4
b) ______________________________	☐1	☐2	☐3	☐4

22. During the past 3 months, how often did you…?

	Never	A bit to try	Once or a couple of times a month	Once or a couple of times a week	Usually every day
Smoke a cigar or cigarillo	☐1	☐2	☐3	☐4	☐5
Use chewing tobacco or snuff	☐1	☐2	☐3	☐4	☐5
Drink alcohol (beer, wine, hard liquor)	☐1	☐2	☐3	☐4	☐5

23. The next questions are about smoking cigarettes. To begin, have you ever IN YOUR LIFE smoked a cigarette, even just a puff (drag, hit, haul)?

☐1 No

☐2 Yes, 1 or 2 times

☐3 Yes, 3 or 4 times

☐4 Yes 5 to 10 times

☐5 Yes, more than 10 times

24. Check the one box that describes you best…

I have never smoked a cigarette, even just a puff ☐1

→ *Go to question 32*

I have smoked cigarettes (even just a puff), but not at all in the past twelve months ☐2

I smoked cigarettes once or a couple of times in the past twelve months ☐3

I smoke cigarettes once or a couple of times each month ☐4

I smoke cigarettes once or a couple of times each week ☐5

I smoke cigarettes every day ☐6

25. Have you ever smoked a <u>whole</u> cigarette (down to or close to the filter)?

- ☐1 No→ *Go to question 28*
- ☐2 Yes

26. How old were you when you smoked a <u>whole</u> cigarette (down to or close to the filter) for the first time?

I was [ ] years old
write age

OR

- ☐7 I don't remember

27. Have you smoked 100 or more <u>whole</u> cigarettes in your life? (100 cigarettes = 4 packs of 25)

- ☐1 No
- ☐2 Yes

28. Have you ever taken cigarette smoke into your lungs for more than one puff?

- ☐1 No → *Go to question 31*
- ☐2 Yes

29. How old were you when you took cigarette smoke into your lungs for more than one puff?

I was [ ] years old
write age

OR

☐7 I don't remember

30. The FIRST FEW TIMES you took cigarette smoke into your lungs, did you experience any of the following...?

	Not at all	A bit	A lot
Coughing	☐1	☐2	☐3
Burning in your throat	☐1	☐2	☐3
Upset stomach	☐1	☐2	☐3
Heart racing/pounding	☐1	☐2	☐3
Dizziness	☐1	☐2	☐3
Nausea	☐1	☐2	☐3
Headache	☐1	☐2	☐3
Other(s)→Describe			
a) ____________________	☐1	☐2	☐3
b) ____________________	☐1	☐2	☐3

31. Would you say that you are someone who has tried smoking cigarettes, but has now stopped smoking completely and (probably) forever...?

☐1 No

☐2 Yes

☐7 I don't know

32. When you see other kids your age smoking cigarettes, how easy is it for you not to smoke?

- ☐1 Very easy not to smoke
- ☐2 Quite easy not to smoke
- ☐3 A bit difficult not to smoke
- ☐4 Very difficult not to smoke

33. How often have you felt like you really need a cigarette?

- ☐1 Never
- ☐2 Rarely
- ☐3 Sometimes
- ☐4 Often

34. How physically addicted to smoking cigarettes are you?

- ☐1 Not at all physically addicted
- ☐2 A little physically addicted
- ☐3 Quite physically addicted
- ☐4 Very physically addicted

35. How mentally addicted to smoking cigarettes are you?

- ☐1 Not at all mentally addicted
- ☐2 A little mentally addicted
- ☐3 Quite mentally addicted
- ☐4 Very mentally addicted

36. How easy is it for you to get cigarettes?

- ☐$_1$ Very easy to get cigarettes
- ☐$_2$ Quite easy to get cigarettes
- ☐$_3$ A bit difficult to get cigarettes
- ☐$_4$ Very difficult to get cigarettes
- ☐$_7$ I don't know (I never tried to get cigarettes)
- ☐$_8$ I don't smoke

INSTRUCTIONS: Now, think carefully about your cigarette smoking experiences during the past 3 months, that is during August, September, and October. Let's begin with October.

37. During October, on how many days did you smoke cigarettes, even just a puff?

- ☐$_1$ None →*Go to question 40*
- ☐$_2$ 1 day
- ☐$_3$ 2-3 days
- ☐$_4$ 4-5 days
- ☐$_5$ 6-10 days
- ☐$_6$ 11-15 days
- ☐$_7$ 16-20 days
- ☐$_8$ 21-30 days
- ☐$_9$ Every day
- ☐$_{77}$ I don't know

38. On the days that you smoked during October, how many cigarettes did you usually smoke each day?

☐1 Less than 1 cigarette (one or a few puffs)

☐2 1 cigarette

☐3 2-3 cigarettes

☐4 4-5 cigarettes

☐5 6-10 cigarettes

☐6 11-15 cigarettes

☐7 16-20 cigarettes

☐8 21-25 cigarettes

☐9 More than 25 cigarettes

☐77 I don't know

39. Write the correct number in the box. During October, the <u>most</u> I smoked in a single day was...

☐ cigarettes

OR

☐ Less than one cigarette (one or a few puffs)

OR

☐77 I don't know

40. Now think about this past September. During September, on how many days did you smoke cigarettes, even just a puff?

- ☐1 None → *Go to question 43*
- ☐2 1 day
- ☐3 2-3 days
- ☐4 4-5 days
- ☐5 6-10 days
- ☐6 11-15 days
- ☐7 16-20 days
- ☐8 21-30 days
- ☐9 Every day
- ☐77 I don't know

41. On the days that you smoked during September, how many cigarettes did you usually smoke each day?

- ☐1 Less than 1 cigarette (one or a few puffs)
- ☐2 1 cigarette
- ☐3 2-3 cigarettes
- ☐4 4-5 cigarettes
- ☐5 6-10 cigarettes
- ☐6 11-15 cigarettes
- ☐7 16-20 cigarettes
- ☐8 21-25 cigarettes
- ☐9 More than 25 cigarettes
- ☐77 I don't know

42. Write the correct number in the box. During September, the <u>most</u> I smoked in a single day was...

☐ cigarettes

OR

☐ Less than one cigarette (one or a few puffs)

OR

☐77 I don't know

43. Now think about this past August. During August, on how many days did you smoke cigarettes, even just a puff?

☐1 None → *Go to question 46*

☐2 1 day

☐3 2-3 days

☐4 4-5 days

☐5 6-10 days

☐6 11-15 days

☐7 16-20 days

☐8 21-30 days

☐9 Every day

☐77 I don't know

44. On the days that you smoked during August, how many cigarettes did you usually smoke each day?

- ☐ 1 Less than 1 cigarette (one or a few puffs)
- ☐ 2 1 cigarette
- ☐ 3 2-3 cigarettes
- ☐ 4 4-5 cigarettes
- ☐ 5 6-10 cigarettes
- ☐ 6 11-15 cigarettes
- ☐ 7 16-20 cigarettes
- ☐ 8 21-25 cigarettes
- ☐ 9 More than 25 cigarettes
- ☐ 77 I don't know

45. Write the correct number in the box. During August, the <u>most</u> I smoked in a single day was...

☐ cigarettes

OR

☐ Less than one cigarette (one or a few puffs)

OR

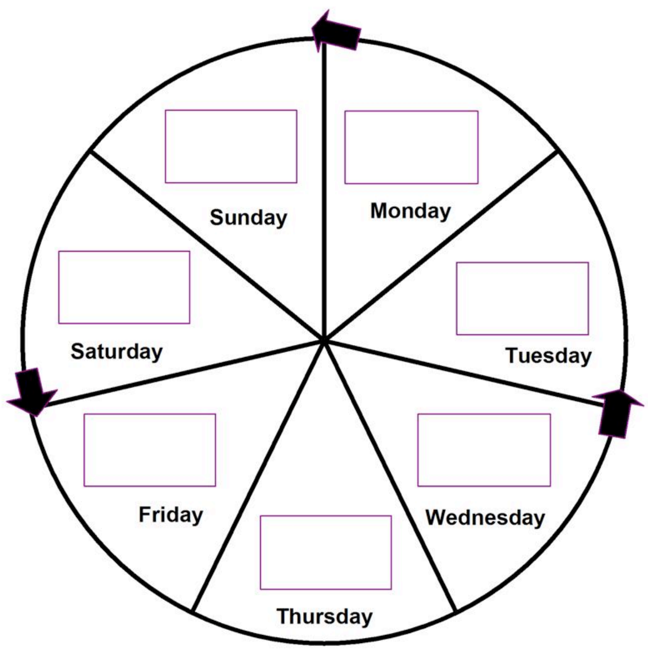
☐ 77 I don't know

46. Now, think about the past 7 days. Did you smoke any cigarettes in the past 7 days, even just a puff?

☐1 No → *Go to* **INSTRUCTIONS box** *at the bottom of the page*

☐2 Yes

47. Starting with yesterday which was ______________, follow the arrows and write in the box how many cigarettes you smoked on each day, even just a puff. If an answer is zero, write in "0".



INSTRUCTIONS

Did you smoke in August, September, or October (even just a puff)?

☐ **YES** → *Please continue the questionnaire.*

☐ **NO** → *Please go to the end of the questionnaire and work quietly on the puzzles.*

48. How often do you smoke cigarettes?

	Never	Sometimes	Often / Always
While waiting for a bus	☐ 1	☐ 2	☐ 3
After a meal	☐ 1	☐ 2	☐ 3
Going to school in the morning	☐ 1	☐ 2	☐ 3
Going home from school in the afternoon	☐ 1	☐ 2	☐ 3
When you are alone	☐ 1	☐ 2	☐ 3
When you are with your friends	☐ 1	☐ 2	☐ 3
At home	☐ 1	☐ 2	☐ 3
On the weekends	☐ 1	☐ 2	☐ 3
At lunch or between classes at school	☐ 1	☐ 2	☐ 3
In the evenings, on school days	☐ 1	☐ 2	☐ 3

49. Do one or both of your parents know that you (have) smoke(d) cigarettes?

☐ 1 No

☐ 2 Yes

☐ 7 I don't know

50. Are you allowed to smoke inside your home?

☐ 1 No

☐ 2 Yes

51. Do you smoke cigarettes now because it is really hard to quit?

- ☐1 No
- ☐2 Sometimes
- ☐3 Often/always
- ☐4 I don't know because I have never tried to quit
- ☐5 Other → Please explain ________________________
- ☐7 I don't know (I smoke so little) or this does not apply to me

52. How much of a cigarette do you usually smoke?

- ☐1 One or a few puffs
- ☐2 Less than half of it
- ☐3 About half of it
- ☐4 Most of the cigarette
- ☐5 Right down to or near the filter
- ☐7 I don't know (I smoke so little) or this does not apply to me

53. Now think about the times when you have cut down or stopped using cigarettes or when you haven't been able to smoke for a long period (like most of the day). How often did you experience the following…?

	Never	Rarely	Sometimes	Often
Feeling irritable or angry	☐ 1	☐ 2	☐ 3	☐ 4
Feeling restless	☐ 1	☐ 2	☐ 3	☐ 4
Increased appetite or hunger	☐ 1	☐ 2	☐ 3	☐ 4
Heart beat slowed down	☐ 1	☐ 2	☐ 3	☐ 4
Feeling nervous, anxious or tense	☐ 1	☐ 2	☐ 3	☐ 4
Feeling down, depressed, miserable or sad	☐ 1	☐ 2	☐ 3	☐ 4
Trouble concentrating	☐ 1	☐ 2	☐ 3	☐ 4
Feeling drowsy or sleepy	☐ 1	☐ 2	☐ 3	☐ 4
Headaches	☐ 1	☐ 2	☐ 3	☐ 4
Upset stomach	☐ 1	☐ 2	☐ 3	☐ 4
Feeling a strong urge or need to smoke	☐ 1	☐ 2	☐ 3	☐ 4
Trouble sleeping	☐ 1	☐ 2	☐ 3	☐ 4

54. On the days that you smoke, when do you *usually* smoke your first cigarette of the day?

- ☐ 1 Right when you wake up
- ☐ 2 In the morning
- ☐ 3 In the afternoon
- ☐ 4 In the evening
- ☐ 5 Another time ______________________________
  When?
- ☐ 7 I don't know (I smoke so little) or this does not apply to me

55. Which cigarette would you most hate to give up? Check ONE box.

- ☐ 1 Last one of the day
- ☐ 2 First one of the morning
- ☐ 3 After meals
- ☐ 4 With alcohol
- ☐ 5 When experiencing negative emotions like being upset
- ☐ 6 After school
- ☐ 7 When I'm at a party or hanging out with friends
- ☐ 8 Other ________________________________
  Describe
- ☐ 77 I don't know (I smoke so little) or this does not apply to me

56. Do you find it difficult not to smoke in places where it's not allowed (at a movie theatre, at home if your parents don't know you smoke)?

- ☐ 1 Not at all difficult
- ☐ 2 A bit difficult
- ☐ 3 Very difficult
- ☐ 7 I don't know (I smoke so little) or this does not apply to me

57. If you are sick with a bad cold or sore throat, do you smoke?

- ☐ 1 No, I stop smoking when I'm sick
- ☐ 2 Yes, but I cut down on the amount I smoke
- ☐ 3 Yes, I smoke the same amount as when I'm not sick
- ☐ 7 I don't know (I smoke so little) or this does not apply to me

58. How deeply do you usually inhale the smoke?

- ☐ 1 Just into my mouth
- ☐ 2 Back into my throat
- ☐ 3 Into my lungs shallow
- ☐ 4 Into my lungs deep
- ☐ 7 I don't know (I smoke so little) or this does not apply to me

59. How true are each of the following statements for you?

	Not at all true	A bit true	Very true
When I am angry, smoking cigarettes calms me down.	☐ 1	☐ 2	☐ 3
Cigarettes are good for dealing with boredom.	☐ 1	☐ 2	☐ 3
When I'm upset with someone, a cigarette helps me cope.	☐ 1	☐ 2	☐ 3
When I'm feeling down, a cigarette makes me feel good.	☐ 1	☐ 2	☐ 3
A cigarette gives me energy when I'm tired.	☐ 1	☐ 2	☐ 3
I enjoy the taste of a cigarette.	☐ 1	☐ 2	☐ 3
When I'm alone, a cigarette helps me pass the time.	☐ 1	☐ 2	☐ 3
Smoking cigarettes calms me down when I feel nervous.	☐ 1	☐ 2	☐ 3
Smoking cigarettes helps me control my weight.	☐ 1	☐ 2	☐ 3
When I have a problem, a cigarette helps me feel better about it.	☐ 1	☐ 2	☐ 3
Smoking cigarettes helps me concentrate on my homework.	☐ 1	☐ 2	☐ 3
Smoking cigarettes relieves tension when I am stressed.	☐ 1	☐ 2	☐ 3

60. How true are each of the following statements for you?

	Not at all true	A bit true	Very true
I feel a sense of control over my smoking. I can "take it or leave it" at any time.	☐1	☐2	☐3
Sometimes even when I tell myself I'm not going to have a cigarette, I find myself smoking anyway.	☐1	☐2	☐3
I consider myself to be a social smoker.	☐1	☐2	☐3
I avoid going to a friend's house where you're not allowed to smoke even though I might enjoy hanging out with him/her.	☐1	☐2	☐3
In situations where I need to go outside to smoke, it's worth it even in cold or rainy weather.	☐1	☐2	☐3
I feel more comfortable with other smokers than with non-smokers.	☐1	☐2	☐3
I go for hours or days without smoking and I don't even realise it.	☐1	☐2	☐3
If I wake up during the night, I feel I need a cigarette.	☐1	☐2	☐3
I can function much better in the morning after I've had a cigarette.	☐1	☐2	☐3
I have cut down or stopped physical activities or sports because of my smoking	☐1	☐2	☐3

61. Do you ever have cravings to smoke cigarettes?

☐1 No → *Go to question 66*

☐2 Yes

62. How often do you have cravings to smoke cigarettes?

☐1 Very rarely

☐2 Sometimes

☐3 Often

☐4 Very often

63. How strong are your cravings to smoke cigarettes?.

- ☐1 Not at all strong
- ☐2 A bit strong
- ☐3 Quite strong
- ☐4 Very strong

64. When you crave a cigarette, how much of the cigarette can satisfy your urge to smoke?

- ☐1 A few puffs
- ☐2 Less than half of the cigarette
- ☐3 About half of the cigarette
- ☐4 The whole cigarette
- ☐5 More than a whole cigarette

65. How much of the craving that you feel is ..?

	None	A little bit	Quite a bit	A whole lot
From your body	☐1	☐2	☐3	☐4
From your head	☐1	☐2	☐3	☐4

66. How true are each of the following statements for you?

	Not at all true	A bit true	Very true
Compared to when I first started smoking, I need to smoke a lot more now to be satisfied.	☐ 1	☐ 2	☐ 3
Compared to when I first started smoking, I can smoke much more now before I start to feel nauseated or ill. OR ☐ 5 I've never felt nauseated or ill from smoking.	☐ 1	☐ 2	☐ 3
I get dizzy or nauseous when I smoke my usual amount of cigarettes	☐ 1	☐ 2	☐ 3
I often run out of cigarettes quicker than I thought I would	☐ 1	☐ 2	☐ 3
I spend a lot of time getting cigarettes (going out of my way to a store where I know they will sell to me; trying to find someone who will buy them for me)	☐ 1	☐ 2	☐ 3
I spend a lot of time smoking cigarettes (chain smoking, smoking a lot throughout the day)	☐ 1	☐ 2	☐ 3
I've stopped hanging out with certain people because of my smoking	☐ 1	☐ 2	☐ 3

67. Now to finish off, a few questions about quitting smoking. At this point in time, how much do you really want to quit smoking cigarettes completely and forever?

☐ 1 Not at all

☐ 2 A little bit

☐ 3 Quite a bit

☐ 4 A whole lot

68. In the <u>past 3 months</u>, did you seriously try to quit smoking completely and forever?

☐ 1 No→ *Go to question 70*

☐ 2 Yes, once

☐ 3 Yes, two or more times

69. Think about the last time you tried to quit smoking. Did you quit smoking completely (for a while)?

- ☐1 No, but I cut down a lot
- ☐2 No, but I cut down a little
- ☐3 No, the amount I smoke didn't change at all
- ☐4 Yes → I quit completely for ______ days (write number of days)
- ☐5 Yes → I quit completely and have remained nonsmoking ever since

70. How confident are you right now that you can or you have quit smoking completely and forever ?

- ☐1 Very confident
- ☐2 Fairly confident
- ☐3 Not very confident
- ☐4 Not at all confident

71. What is the MAIN REASON that you don't quit smoking now. Check ONE box only.

- ☐1 I don't want to, I enjoy smoking
- ☐2 It's become a routine that would be really hard to break
- ☐3 It's too hard because everyone around me smokes
- ☐4 My cravings for cigarettes are too strong
- ☐5 I have too much stress in my life
- ☐6 I feel uncomfortable when I stop smoking
- ☐7 I don't need to (because I smoke so little now)
- ☐8 Something else → Describe ____________________

AQ26. Do you plan to quit smoking completely and forever (please answer each question)…

	NO	YES	I don't know
In the next month?	☐1	☐2	☐7
In the next 6 months?	☐1	☐2	☐7

THAT'S ALL! THANK YOU VERY MUCH.

Appendix 2. Québec Child and Adolescent Health and Social Survey questionnaire for children

SANTÉ QUÉBEC

Questionnaire for children

tell us about your health

HEALTH AND SOCIAL SURVEY

of Québec children and youth

QE

SANTÉ QUÉBEC
1200, avenue McGill College, bureau 700
Montréal (Québec) H3B 4J8
(514) 873-4749

N° de dossier :	
N° de l'interviewer :	| | |
ADM ___	LA _2_
Date de réception :	___ jr | ___ ms | ___ an

Instructions

In this questionnaire, we ask you questions about your family and school. We also ask you about things you like to do, and your feelings about certain things.

This is not a test. There are no right or wrong answers.

Simply answer each question indicating what you really think.

Your name is not written on this questionnaire. No one, even your parents or teacher, will ever know what you answered.

Answer each question.

To answer, make an X in the circle ◯, as follows ⓧ

Examples

You are …

1 ⓧ A boy
2 ◯ A girl

or write a number

How old are you?

___9___ years old

General information

1. How old are you?

___________ years old

2. You are...

- 1 • A boy
- 2 • A girl

3. What language do you usually speak with your friends?

- 01 • French
- 02 • English
- 03 • Italian
- 04 • Greek
- 05 • Spanish
- 06 • Portuguese
- 07 • Chinese
- 08 • Vietnamese
- 09 • Arabic
- 96 • Other language • *What?* ________________________________

Your school and you

4. What grade are you in?

- 1 • 1st grade
- 2 • 2nd grade
- 3 • 3rd grade
- 4 • 4th grade
- 5 • 5th grade
- 6 • 6th grade
- 7 • 7th grade

5. Have you ever had a remedial teacher help you with reading or pronunciation?

1 • Yes
2 • No
8 • Don't know

6. Since the beginning of the school year, have you seen any of the following people *because of a personal problem*?

	Yes	No
A. A psychologist or social worker	1 •	2 •
B. A nurse	1 •	2 •
C. Other • *Who* ? ______________________________	1 •	2 •

7. For each sentence, indicate whether it is true or false.

	True	False
A. I'm not getting very good marks at school this year	1 •	2 •
B. I know that I'm capable of getting good marks at school this year	1 •	2 •

8. How much time do you spend every day on doing your homework or studying?

1 • None
2 • 30 minutes or less
3 • About an hour
4 • More than an hour

9. In general, do you like school?

1 • Yes, I do
2 • So, so
3 • No, I don't

10. For each sentence, indicate ?Often," ?Sometimes" or ?Never."

My parents or the adults I live with...	**Often**	**Some-times**	**Never**
A. encourage me to do well in school	1 •	2 •	3 •
B. check to see if I'm doing my homework well	1 •	2 •	3 •
C. are interested in what I'm doing at school	1 •	2 •	3 •
D. go to parent-teacher meetings to discuss or pick up my report card	1 •	2 •	3 •

11. Are you afraid of something when you go to school or come back home?

1 • Often
2 • Sometimes
3 • Never • *Go to question 13*

12. Why are you afraid? Answer yes or no for each reason.

	Yes	**No**
A. I'm afraid of being hit by a car or a truck	1 •	2 •
B. I'm afraid of being beaten up or robbed	1 •	2 •
C. Some adults make me afraid or scared	1 •	2 •
D. I'm afraid of something else • *What is it?* ___________________________	1 •	2 •

13. Indicate how often each of the following has happened. *Since school began in September, at school or on the way to school...*

	Often	Some-times	Never
A. I've been called names	1 •	2 •	3 •
B. someone has told me they're going to hit me or break something that's mine	1 •	2 •	3 •
C. someone has hit me (slapped, punched, kicked), bullied me or pushed me around violently	1 •	2 •	3 •
D. someone has offered me money to do bad things (rob, threaten or beat someone)	1 •	2 •	3 •
E. I've been taxed (someone stole something from me by threatening me)	1 •	2 •	3 •

14. How do you usually get to school?

1 • Schoolbus
2 • Walk • *How many minutes does it take* ? __________
3 • Metro and/or bus
4 • Car

People you're close to

There may be people in your life you can share secrets with, share your happy times, share your sad times.

15. Do you have someone who can help you if you have a problem?

- 1 • Yes
- 2 • No

16. Do you think the following people really listen to you and help you feel better when you need it?

If you never or rarely see the person, put an X in the last column.

	This person will listen to you...			Doesn't apply, or never see her or him
	a lot	a little	not at all	
A. Your father or the adult man you usually live with	1 •	2 •	3 •	4 •
B. Your mother or the adult woman you usually live with	1 •	2 •	3 •	4 •
C. One of your brothers or sisters	1 •	2 •	3 •	4 •
D. One of your friends	1 •	2 •	3 •	4 •
E. Your teacher	1 •	2 •	3 •	
F. Someone else • *Who:* ____________________	1 •	2 •	3 •	

17. *During the past 6 months,* have you ever told someone something that was bothering you or was very important to you?

1 • Yes
2 • No

18. When you feel sad or very happy, do you talk to someone about it, share it with someone?

1 • Often
2 • Sometimes
3 • Never

You and your parents

If you don't usually live with your mother or other female adult

- *Go to question 20*

19. Thinking about *the last month*, please answer each of the following questions about your mother or the adult woman you usually live with, such as your stepmother, or the wife or girlfriend of your father.

- *Your answers should refer to only one person.*

	Often	Some-times	Never
A. Does she compliment you for the good things you do?	1 •	2 •	3 •
B. Is she affectionate with you? (E.g. hugs you, smiles at you, kisses you or says nice things to you)	1 •	2 •	3 •
C. Is she too busy to be able to talk with you about things that interest you?	1 •	2 •	3 •
D. Do you have good times together?	1 •	2 •	3 •
E. Does she tell you what to do, even for small, unimportant things?	1 •	2 •	3 •
F. Does she go through your things without your permission?	1 •	2 •	3 •
G. Is she on your back (on your case)?	1 •	2 •	3 •
H. Does she make fun of you or ridicule you in front of others?	1 •	2 •	3 •
I. Does she say things that hurt you or make you feel bad?	1 •	2 •	3 •

If you don't usually live with your father or other adult male

- *Go to question 21*

20. Thinking about the last month, please answer each of the following questions about your father or the adult man you usually live with, such as your stepfather, or the husband or boyfriend of your mother.

- *Your answers should refer to only one person.*

	Often	Some-times	Never
A. Does he compliment you for the good things you do?	1 •	2 •	3 •
B. Is he affectionate with you? (E.g. hugs you, smiles at you, kisses you or says nice things to you)	1 •	2 •	3 •
C. Is he too busy to be able to talk with you about things that interest you?	1 •	2 •	3 •
D. Do you have good times together?	1 •	2 •	3 •
E. Does he always tell you what to do, even for small, unimportant things?	1 •	2 •	3 •
F. Does he go through your things without your permission?	1 •	2 •	3 •
G. Is he on your back (on your case)?	1 •	2 •	3 •
H. Does he make fun of you or ridicule you in front of others?	1 •	2 •	3 •
I. Does he say things that hurt you or make you feel bad?	1 •	2 •	3 •

21. Does it ever happen that your parents or adults you live with…

	Often	Some-times	Never
A. insult, yell at each other, or say bad or hurtful things to each other?	1 •	2 •	3 •
B. hit each other, physically beat or hurt each other?	1 •	2 •	3 •

About you

22. For each of the following sentences, indicate which answer best describes how you feel.

	True	Rather true	Rather false	False
A. I do a lot of important things	1 •	2 •	3 •	4 •
B. In general, I like myself as I am	1 •	2 •	3 •	4 •
C. All in all, there are a lot of reasons why I can be proud of myself	1 •	2 •	3 •	4 •
D. I can do things as well as most people	1 •	2 •	3 •	4 •
E. Other people think I am a good person	1 •	2 •	3 •	4 •
F. I have many good qualities	1 •	2 •	3 •	4 •
G. I am just as good as most people	1 •	2 •	3 •	4 •
H. When I do something, I do it well	1 •	2 •	3 •	4 •

Changes in your body

As you grow up, your body changes. These changes influence your health. This is why we're asking you the following questions.

23. Do you have any hair under your arms or around your private parts (between your legs)?

- 1 • It has not yet started growing
- 2 • It has barely started growing
- 3 • It has definitely started growing
- 4 • I think it has stopped growing

If you are a boy • Go to question 26

24. Have your breasts begun to grow?

- 1 • They have not yet started growing
- 2 • They have barely started growing
- 3 • They have definitely started growing
- 4 • I think they have stopped growing

25. Have you begun to have periods, to menstruate?

- 1 • Yes
- 2 • No

If you are a girl • Go to question 28

26. Have you noticed a deepening in your voice?

1 • It has not yet started changing
2 • It has barely started changing
3 • It has definitely started changing
4 • I think it has stopped changing

27. Do you have any hair on your face?

1 • I don't have any yet
2 • It has just begun to grow
3 • I already have quite a bit
4 • I think my facial hair has filled in and will remain the same

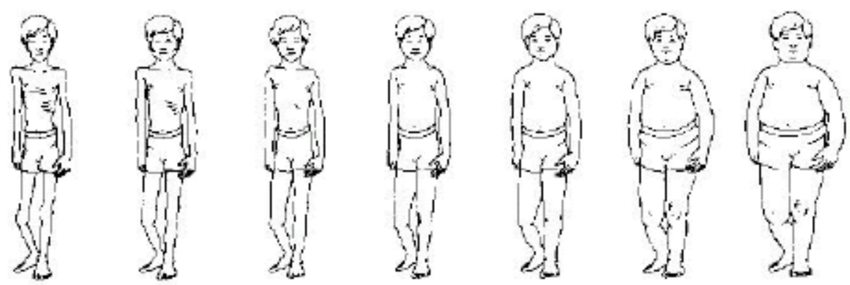
Questions for girls and boys

28. Indicate the picture that looks the most like you. (What you look like now).

Girls

1 • 2 • 3 • 4 • 5 • 6 • 7 •

Boys



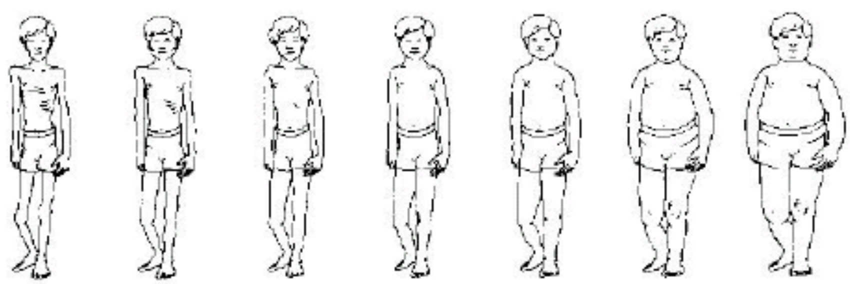
1 • 2 • 3 • 4 • 5 • 6 • 7 •

29. Indicate the picture that you want to look like the most.

Girls

1 • 2 • 3 • 4 • 5 • 6 • 7 •

Boys



1 • 2 • 3 • 4 • 5 • 6 • 7 •

30. Are you currently doing anything about your weight?

1 • I'm trying to lose weight
2 • I'm trying to gain weight
3 • I'm not doing anything about my weight

31. Do any of the following people ever push you to lose weight?

	Yes	No	I have no brother or sister
A. Your mother, father or the adult who takes care of you	1 •	2 •	
B. Your brother or sister	1 •	2 •	3 •
C. One of your friends	1 •	2 •	

Physical activity

32. *In the past week* (Monday to Sunday), indicate the days you did the following activities, *for at least 15 minutes straight.*

Physical activities practised during physical education classes at school should be indicated in «a» only.

	I didn't do any	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
a. Physical Education classes at school	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
b. Bicycling	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
c. Skipping rape, playing elastics	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
d. Dodge-ball, wall-ball (stand-all), catch	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
e. Playing tag, racing, relay racing	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
F. In-line skating (rollerblading) skateboarding	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
g. Swimming	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
h. Badminton, tennis	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
i. Jazz or classical ballet	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
j. Gymnastics (on the floor, or using equipment)	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
k. Basketball	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
l. Volleyball	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
m. Soccer	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •

Continuing ...

32. *In the past week* (Monday to Sunday), indicate the days you did the following activities, *for at least 15 minutes straight.*

	I didn't do any	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
n. Hockey (ice or ball)	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
o. Skating (ice)	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
p. Sliding, tobogganing	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
q. Snowboarding, downhill skiing	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
r. Cross-country skiing	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
s. Other *If you did other activities, please write the first one, then indicate which day(s) you did it, etc.*								
• *Name them:*								
• ____________	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
• ____________	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •
• ____________	0 •	1 •	2 •	3 •	4 •	5 •	6 •	7 •

•

33. Compared to last year, would you say that you do…

- 1 • more sports or physical activity?
- 2 • as much sports or physical activity?
- 3 • less sports or physical activity?

34. In general, compared to other children your age, would you say that you do…

- 1 • more sports or physical activity?
- 2 • as much sports or physical activity?
- 3 • less sports or physical activity?

Your other activities

35. In the past week *<u>for your own enjoyment, not school</u>*, did you read …

	Yes	No
A. a newspaper?	1 •	2 •
B. a magazine?	1 •	2 •
C. a book?	1 •	2 •

36. In the past week, did you go to…

	Yes	No
A. the theatre to see a movie?	1 •	2 •
B. an arcade to play video or computer games?	1 •	2 •
C. a music concert?	1 •	2 •
D. an arena or gym to watch a game?	1 •	2 •

37. How many hours a day do you usually watch television or videos (don't include video games)?

1. Week days: __________ hours a day
2. Weekends: __________ hours a day

38. Do you have a computer at home?

1 • Yes
2 • No • *Go to question 40*

39. Do you use it …

1 • often
2 • sometimes
3 • never

Smoking and alcohol

40. Have you ever tried smoking (cigarettes), even just a few puffs?

1 • Yes
2 • No • *Go to question 42*

41. Have you ever smoked a whole cigarette?

1 • Yes
2 • No

42. During the past 12 months, did you drink <u>at least one glass</u> of wine, beer or liquor (gin, rye, vodka)?

1 • Yes, only on special occasions
2 • Yes, at least once a month
3 • Yes, at least once a week
4 • No, never

43. Have you ever tried drugs, for example marijuana, hash or glue?

1 • Yes
2 • No

You and your health

44. In general, is your health...

- 1 • excellent?
- 2 • quite good?
- 3 • not very good?

45. Do you ever experience any of the following?

	Often	Sometimes	Never
A. Headache	1 •	2 •	3 •
B. Stomach ache	1 •	2 •	3 •
C. Sore back	1 •	2 •	3 •
D. Difficulty sleeping	1 •	2 •	3 •
E. Dizziness	1 •	2 •	3 •
F. Other health problems			
• *What?* ____________________	1 •	2 •	3 •

46. *During the past 12 months,* did you ever seriously consider attempting suicide (killing yourself)?

- 1 • Yes
- 2 • No

47. *During the past 12 months,* did you use any of the following, as a ...

Read the type of vehicle. In «c», only those who have used it should answer. To be a conductor is to hold the steering and the pedals.

	 All Terrain vehicle	 Snowmobile	 SeaDoo	 Moped (mobylette)	 Scooter	 Motorcycle	 Car
a. driver?	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No
b. passenger?	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No	1• Yes 2• No
c. If "yes", did you wear any safety equipment?	*Do you wear a helmet?* **Helmet** 1• Always 2• Sometimes 3• Never	*Do you wear a helmet?* **Helmet** 1• Always 2• Sometimes 3• Never	*Do you wear a lifejacket?* **Lifejacket** 1• Always 2• Sometimes 3• Never	*Do you wear a helmet?* **Helmet** 1• Always 2• Sometimes 3• Never	*Do you wear a helmet?* **Helmet** 1• Always 2• Sometimes 3• Never	*Do you wear a helmet?* **Helmet** 1• Always 2• Sometimes 3• Never	*Do you wear a safety belt?* **Safety belt** 1• Always 2• Sometimes 3• Never

48. *During the past 12 months,* did you do any of the following activities?

		If "yes" did you wear a helmet?
a. Bicycling 	Yes 1 • • • • No 2 •	Always 1 • Sometimes 2 • Never 3 •
b. In-line skating (Rollerblading) 	Yes 1 • • • • No 2 •	Always 1 • Sometimes 2 • Never 3 •
c. Skateboarding 	Yes 1 • • • • No 2 •	Always 1 • Sometimes 2 • Never 3 •

Your diet

49. In the past 5 school days, how many mornings did you eat or drink something before school started? Don't count coffee, tea or water.

1 • 5 mornings (every day)
2 • 3 to 4 mornings
3 • 1 to 2 morning(s)
4 • Never

Now let's talk about every day of the week.

50. *In the past 7 days,* how many times did you eat supper…

	Never	1 or 2 time(s)	3 to 5 times	6 or 7 times
A. alone?	1 •	2 •	3 •	4 •
B. with one or several members of your family?	1 •	2 •	3 •	4 •
C. with the baby-sitter?	1 •	2 •	3 •	4 •
D. with your friends?	1 •	2 •	3 •	4 •

51. *In the last 7 days*, how many times …

	Never	1 or 2 time(s)	3 to 5 times	6 or 7 times
A. did you eat a meal in a restaurant?	1 •	2 •	3 •	4 •
B. did you have a snack in a restaurant?	1 •	2 •	3 •	4 •
C. did you (or your family) have food delivered to your home from a restaurant?	1 •	2 •	3 •	4 •

52. *In the last 7 days,* how many times did you consume the following foods and beverages?

		Per week			Per day		
	Not once	1-2 time(s)	3-4 times	5-6 times	1-2 time(s)	3-4 times	5 times or more
Milk (as a beverage)	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Raw vegetables and salads	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Cooked vegetables (not including potatoes)	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Fruit(s) - fresh, canned, frozen or cooked	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Bread, bagel, pita or other types of bread a. White	1 •	2 •	3 •	4 •	5 •	6 •	7 •
b. Whole-wheat (rye, 6-grain, etc.)	1 •	2 •	3 •	4 •	5 •	6 •	7 •

53. Today's date:

				1	9	9	9

Day Month Year

Thanks for participating! •

If you have any comments or suggestions about this questionnaire, please write them in the space below.

Appendix 3. Québec Child and Adolescent Health and Social Survey questionnaire for adolescents

SANTÉ QUÉBEC

Questionnaire for adolescents and teenagers

tell us about your health

HEALTH AND SOCIAL SURVEY

of Québec children and youth

QA

SANTÉ QUÉBEC
1200, avenue McGill College, bureau 700
Montréal (Québec) H3B 4J8
(514) 873-4749

N° de dossier :

N° de l'interviewer :

ADM ___ LA 2

Date de réception : jr ms an

Instructions

In this questionnaire, we ask you questions about your family and school. We also ask you about things you like to do, and your feelings about certain things.

This is not a test. There are no right or wrong answers. Simply answer each question, indicating what you really think or feel.

Your name is not written on this questionnaire. No one other than Santé Québec will ever know your answers. You can be sure they will remain completely **confidential**.

Thank you for participating!

Many of the questions in this questionnaire have several possible answers. Choose the answer best suited to your situation. Indicate your response by circling the number or by writing an appropriate figure.

Here are a few sample questions and answers to illustrate what we mean:

Example A *Circle your answer.*

During the past 7 days, how many times did you...

	Not once	1 or 2 times	3 to 5 times	6 or 7 times
A. eat a meal in a restaurant?	(1)	2	3	4
B. have a snack in a restaurant?	1	(2)	3	4

Example B *Fill in the blank.*

How old are you? __16__ Years old

Example C *Fill in the blank.*

To what ethnocultural group would you say you belong? (for example: Jamaican, Haitian, Chilean, Lebanese, Vietnamese, Quebecer, ...)

__Chinese__

General information

1. How old are you? __________ years old

2. Indicate the day, month and year of your birth.

> Example: if you were born on August 25, 1985,
> enter: 25 08 1985

Day	Month	Year
☐☐	☐☐	1 9 ☐☐

3. You are...

A boy 1
A girl 2

4. What language do you speak *most often* with your closest friends?

- *Indicate the one your use most often.*

French 01
English 02
Italian 03
Greek 04
Spanish 05
Portuguese 06
Chinese 07
Vietnamese 08
Arabic 09
Other • *Please specify:* ______________________ 96

5. To what ethnocultural group would you say you belong? (for example: Jamaican, Haitian, Chilean, Lebanese, Vietnamese, Quebecer, ...)

____

Your school and you

6. What grade are you in?

I'm in primary school in:	1st grade	01
	2nd grade	02
	3rd grade	03
	4th grade	04
	5th grade	05
	6th grade	06
	7th grade	07
I'm in high school in:	Secondary I	08
	Secondary II	09
	Secondary III	10
	Secondary IV	11
	Secondary V	12
	Secondary VI	13
	Individualized Path for Learning (IPL, Special learning group)	14

If you are in secondary • Go to question 8

7. Have you ever received help from a remedial teacher for reading or pronunciation ?

Yes	1
No	2
Don't know	8

If you are in primary • Go to question 9

8. If you are in high school, have you ever been registered in an individualized path for learning (special learning group) ?

Yes	1
No	2
Don't know	8

9. Compared to other people in your class, are your marks in English...

better than average?	1
average?	2
below average?	3

10. For each of the following statements, indicate the response which best applies to you.

	True	False
A. I'm not doing very well at school this year	1	2
B. In general, I'm quite sure of succeeding at what I set out to do	1	2
C. I have confidence in my abilities to succeed in school	1	2
D. This year, I think I'll fail at least two subjects	1	2
E. I succeed better at the things I do outside of school	1	2

11. During a normal school week, about how many hours, in total, do you devote to your homework and studying?

Less than 1 hour a week 1
From 1 to 2 hour(s) a week 2
From 3 to 5 hours a week 3
From 6 to 10 hours a week 4
From 11 to 20 hours a week 5
More than 20 hours a week 6

12. How far do you intend to go with your education?

High School Diploma 1
Vocational or Trade School Diploma 2
College Diploma 3
University Degree 4
I don't think I'll go further than this year 5
Don't know 8

13. Compared with your classmates, would you say that your family's economic situation is...

better than theirs? 1
the same as theirs? 2
worse than theirs? 3

If you are in primary • Go to question 16

14. The following questions are on how you and your parents relate to your school.

- *For each of the following statements, indicate the response that best describes your situation.*

	Completely agree	Somewhat agree	Somewhat disagree	Completely disagree
A. I feel comfortable at my school	1	2	3	4
B. At my school, they take into account the opinion of the students when making rules and regulations	1	2	3	4
C. The students have some responsibilities in organizing extracurricular school activities	1	2	3	4
D. Some of my teachers will listen to what I have to say when I need to talk about my problems	1	2	3	4
E. I can easily meet with my teachers to discuss various personal problems	1	2	3	4

15. For each of the following statements, indicate the response that best describes your situation.

My parents or the adults I live with...	Often	Sometimes	Never
A. Encourage me to do well in school	1	2	3
B. keep informed of what I do during the day at school	1	2	3
C. go to meet with the teachers to pick up my report (when this event is organized)	1	2	3

16. *Since September*, at your school or on the way to and from school, have you experienced the following?

- *For each statement, answer what best describes your experience.*

	Often	Sometimes	Never
A. You've been insulted or called names	1	2	3
B. Someone has threatened to hit you or break something belonging to you	1	2	3
C. You've experienced unwanted sexual touching, like fondling, etc.	1	2	3
D. You've been hit (beat up, punched, kicked, bullied) or pushed around violently	1	2	3
E. You've been offered money to do bad or illegal things (for example rob, threaten or hit someone, etc.)	1	2	3
F. You've been "taxed" (someone has robbed you of money or objects after threatening you)	1	2	3

17. Do you feel insecure (afraid) when you go to and from school?

Often 1
Sometimes 2
Never . . . . 3 • *Go to question 19*

18. Why do you feel insecure or afraid?

For each of the following • *Please answer yes or no.*

	Yes	No
A. Traffic is dangerous	1	2
B. There are gangs or there is taxing	1	2
C. Other reason(s) • *Please specify:*	1	2

19. How do you usually get to school?

• *If you often use more than one, indicate all for them.*

School bus 1
Walk • *How many minutes does it take (one-way)?* ________ minutes . 2
Metro and/or bus 3
Car 4

You and work

20. Do you currently have a job in which you work for pay?

Yes 1
No . . . . 2 • *Go to question 23*

21. How many hours a week do you generally work for pay?

__________ hours a week

22. Why do you work?

- *For each of the following reasons, indicate whether it was "Very important", "Important" or "Not important at all", in making your decision.*

	Very important	Important	Not important at all
A. To pay for things I would like to have	1	2	3
B. To help my parents	1	2	3
C. To pay for essential things I need for school	1	2	3
D. To get experience in working	1	2	3
E. To save for the futur	1	2	3
F. Other • *Please specify:*	1	2	3

About you

23. For each of the following statements, indicate the response which best describes your situation.

	Completely agree	Somewhat agree	Somewhat disagree	Completely disagree
A. I think I am someone who has something valuable to offer, at least as much as other people do	1	2	3	4
B. I think I have a certain number of good qualities	1	2	3	4
C. Everything considered, I tend to think I'm a failure	1	2	3	4
D. I think I am capable of doing things as well as other people my age	1	2	3	4
E. There's little reason to be proud of myself	1	2	3	4
F. I have a positive attitude towards myself	1	2	3	4
G. Overall, I'm satisfied with myself	1	2	3	4
H. I find it difficult to accept myself as I am	1	2	3	4
I. Sometimes I think I'm really useless	1	2	3	4
J. I've thought of myself as a good-for-nothing on occasion	1	2	3	4

24. Some young people do things that are not exactly correct or legal. Think about the *last 6 months*, and answer yes or no for each statement.

And don't forget, nobody you know will ever see your answers!

	Yes	No
A. I've stayed out late at night (for example, until 4 or 5 o'clock) against the rules set by my parents	1	2
B. I've run away from home at least twice	1	2
C. I've often threatened or bullied other people	1	2
D. I've often started fights	1	2
E. I've used a weapon (knife, gun, chain, stick, broken bottle, brass knuckles, etc.) in a fight or to scare someone	1	2
F. I've deliberately done harm to or hurt someone	1	2
G. I've deliberately mistreated or harmed animals	1	2
H. I've robbed someone directly (mugged someone, stolen their wallet, committed armed robbery)	1	2
I. I've forced someone against their will to do something sexual with me	1	2
J. I've deliberately set fire to something to cause damage or hurt someone	1	2
K. I've committed vandalism (damaging property, walls, cars, public property, etc.)	1	2
L. I've broken into someone's home, apartment or car by breaking a window or forcing a door	1	2
M. I've frequently lied to get things or favours, or to avoid duties and obligations	1	2
N. I've shoplifted, or committed fraud more than once	1	2
O. I've often missed school without a valid reason	1	2
P. I've "taxed" someone (threatened in order to rob him/her)	1	2
Q. I've carried a weapon on me (knife, chain, brass knuckles, etc.)	1	2

The people around you

There may be people in your life you can share secrets with, share your happy times, share your sad times.

25. Do you have someone who can help you if you have a problem?

Yes 1
No 2

26. Do you think the following people would really listen to you and help you feel better if you really needed it?

- *If you never or rarely see the person, circle the number in the last column.*

	This person will listen to you ...			Doesn't apply to you or you rarely see this person
	a lot	a little	not at all	
A. Your father or the adult man you live with the most	1	2	3	4
B. Your mother or the adult woman you live with the most	1	2	3	4
C. One of your brothers or sisters	1	2	3	4
D. One of your friends	1	2	3	4
E. One of your teachers	1	2	3	X
F. Someone else • *Who?*	1	2	3	X

27. *During the 6 last months,* have you told someone something that was bothering you or was very important to you?

Yes 1
No . . . . 2 • *Go to question 29*

28. If « yes », were you satisfied with the way they listened to you and what they said to help?

Satisfied 1
More or less satisfied 2
Unsatisfied 3

29. When you feel sad or very happy, do you talk to someone about it, share it with someone?

Often 1
Sometimes 2
Never 3

You and your parents

If you don't usually live with your mother or other adult woman • Go to question 31.

30. *During the last month*, how would you describe your relationship with your mother or the adult woman you usually live with such as your stepmother, or the wife or girlfriend of your father?

- *Your answers should refer to only one person.*

	Very often	Often	Some-times	Rarely	Never
A. Does she compliment you for the good things you do?	1	2	3	4	5
B. Is she affectionate with you? (She hugs you, smiles at you, kisses you or say nice things to you)	1	2	3	4	5
C. Is she too busy for you to be able to talk to her about things that interest you?	1	2	3	4	5
D. Do you have good times together?	1	2	3	4	5
E. Does she tell you what to do, even for small, unimportant things?	1	2	3	4	5
F. Does she go through your things without your permission?	1	2	3	4	5
G. Is she on your back (on your case)?	1	2	3	4	5
H. Does she make fun of you or ridicule you in front of others?	1	2	3	4	5
I. Does she say things that hurt you or make you feel bad?	1	2	3	4	5

If you don't usually live with your father or other adult man • Go to question 32.

31. *During the last month,* how would you describe your relationship with your father or the adult man you usually live with such as your stepfather, or the husband or boyfriend of your mother?

- *Your answers should refer to only one person.*

	Very often	Often	Some-times	Rarely	Never
A. Does he compliment you for the good things you do?	1	2	3	4	5
B. Is he affectionate with you? (He hugs you, smiles at you, kisses you or say nice things to you)	1	2	3	4	5
C. Is he too busy for you to be able to talk to him about things that interest you?	1	2	3	4	5
D. Do you have good times together?	1	2	3	4	5
E. Does he tell you what to do, even for small, unimportant things?	1	2	3	4	5
F. Does he go through your things without your permission?	1	2	3	4	5
G. Is he on your back (on your case)?	1	2	3	4	5
H. Does he make fun of you or ridicule you in front of others?	1	2	3	4	5
I. Does he say things that hurt you or make you feel bad?	1	2	3	4	5

32. Does it ever happen that your parents or the adults you live with ...

	Often	Sometimes	Never
A. insult, yell at each other, or say bad or hurtful things to each other?	1	2	3
B. hit each other, physically beat or hurt each other?	1	2	3

How you feel

33. *During the past week*, how often did you ...

	Never	Once in a while	Fairly often	Very often
A. feel nervous or shaky inside?	1	2	3	4
B. feel tense, stressed or under pressure?	1	2	3	4
C. feel afraid or fearful?	1	2	3	4
D. lose your temper, get angry at someone or something?	1	2	3	4
E. feel easily annoyed or irritated?	1	2	3	4
F. feel critical of others?	1	2	3	4
G. get angry over things that weren't very important?	1	2	3	4
H. feel lonely?	1	2	3	4
I. feel bored or have little interest in things?	1	2	3	4
J. cry easily, or feel like crying?	1	2	3	4
K. feel down, discouraged?	1	2	3	4
L. feel hopeless about the future?	1	2	3	4
M. have your mind go blank?	1	2	3	4
N. have trouble remembering things?	1	2	3	4

If you answered « never » to all the above questions • Go to question 37.

If you circled 2, 3 or 4 to one or more of the above questions, answer the following questions.

34. How long have you had these feelings or experiences?

Less than 2 weeks 1
2 or 3 weeks 2
A month 3
A few months 4
A year or more 5

35. *During the past 12 months*, did you consult a health professional or any other adult who could give you some advice (teacher, guidance counsellor, etc.), because of these feelings or problems?

Yes . . . . 1 • *Go to question 37*
No 2

36. *During the past 12 months,* what stopped you from asking someone to help you with these feelings or problems?

- *Choose only the main reason.*

I didn't know who to go to	01
It would have taken too much time	02
I was afraid my parents or other people would find out	03
I thought that my feelings or problems would go away over time	04
It wasn't important enough to seek help	05
I thought I could take care of it myself	06
The person whom I wanted to see wasn't available	07
Other reason • *Please specify:* ______________	96
Don't know	98

37. *During the past 12 months,* did you ever *seriously* consider attempting suicide (taking your own life)?

Yes	1	
No	2	• *Go to question 43*

38. If you thought of suicide *in the past 12 months,* did you plan a particular method, time or place to do it?

Yes	1
No	2

39. *During the past 12 months,* how many times did you actually attempt suicide?

Never	1
Once	2
More than once	3

40. *During the past 12 months,* did you tell someone that you were considering suicide?

No, no one	1
Yes, a friend	2
Yes, one of my parents	3
Yes, an adult from school	4
Yes, someone else • *Who?* ______________	5

41. *During the past 12 months,* did you consult a health professional or other adult who can give advice (teacher, guidance counsellor, etc.) after you thought about or attempted suicide?

Yes	1	• *Go to question 43*
No	2	

42. *During the past 12 months,* what stopped you from asking someone to help you sort out your thoughts or attempt(s) at suicide?

- *Choose only the main reason.*

I didn't know who to go to	01
It would have taken too much time	02
I was afraid my parents or other people would find out	03
I thought that my feelings or problems would go away over time	04
It wasn't important enough to seek help	05
I thought I could take care of it myself	06
The person whom I wanted to see wasn't available	07
Other reason • *Please specify:*______________________	96
Don't know	98

Puberty and sexuality

Biological changes in your body during puberty influence various aspects of your health. This is why we are asking the following questions.

43. Do you have any body hair (meaning underarm or pubic hair)?

It has not yet started growing	1
It has barely started growing	2
It has definitely started growing	3
I think it has stopped growing	4

If you are male • Go to question 59.

44. Have your breasts begun to grow?

They have not yet started growing	1
They have barely started growing	2
They have definitely started growing	3
I think they have stopped growing	4

45. Have you begun to menstruate (have periods)?

Yes	1
No	2

YOUR RELATIONSHIPS WITH BOYS.

The following questions are about your perceptions with respect to sexuality. Even if you feel you are too young to have had these experiences, we would like to know how you think you would respond in the following situations.

46. For each of the following statements about your sexuality, indicate the degree to which you agree or disagree:

I think I'd be capable of...	**Completely agree**	**Moderately agree**	**Somewhat agree**	**Completely disagree**
A. going out with a boy without feeling obligated to have a sexual relationship with him	1	2	3	4
B. waiting until I feel ready before having a sexual relationship	1	2	3	4
C. choosing when and with whom I have sexual relations	1	2	3	4
D. arranging a means of contraception when I need it	1	2	3	4
E. telling a boy how he can give me pleasure sexually	1	2	3	4
F. speaking about contraception with him before having sexual relations with him	1	2	3	4
G. refusing a sexual practice I don't feel comfortable with	1	2	3	4
In a sexual relationship, I think I'd be capable of ...				
H. taking the initiative	1	2	3	4
I. convincing a boy to use a condom	1	2	3	4

47. Have you *ever* gone out with a boy? Going out with someone means spending quite intimate moments with him. This can mean for one evening or seeing him for several weeks or months.

Yes 1
No .... 2 • *Go to question 58*

48. *During the past 12 months*, have you gone out with one or more boys?

Yes 1
No .... 2 • *Go to question 58*

49. If « yes », *during the past 12 months*, how many times did one or more of these boys (boyfriend or casual partner) do any of the following?

	Never	Once	Twice	3 or more times
A. A boy hurt my feelings (for example, by insulting me in front of people, checking who I go out with, preventing me from seeing my friends, etc.)	0	1	2	3
B. A boy forced me to have sexual contact with him when I didn't want to by pressuring me or harassing me (sexual contact means kissing, petting, touching, sexual intercourse)	0	1	2	3
C. A boy forced me to have sexual contact with him when I didn't want to by threatening to use force or by physically forcing me (sexual contact means kissing, petting, touching, sexual intercourse)	0	1	2	3
D. A boy threw something at me which could have hurt me	0	1	2	3
E. A boy grabbed me and held me by my arms	0	1	2	3
F. A boy pushed me around or shook me	0	1	2	3
G. A boy slapped me	0	1	2	3
H. A boy hurt me by punching me, kicking me, using a weapon on me, or using an object as a weapon on me	0	1	2	3

In the following questions, voluntarily means with your consent.

50. Have you had sexual intercourse (penetration of the penis) voluntarily?

Yes 1
No . . . . 2 • *Go to question 58*

51. Since the first time, with how many different boys have you had sexual intercourse (with penetration) voluntarily?

A. With boys who were your boyfriends? • ________ boy(s)

B. With boys who were not your boyfriends? • ________ boy(s)

52. How old were you when you had sexual intercourse for the first time voluntarily?

________ years old

53. The *first* time you had sexual intercourse ...

A. Who was it with?

With a boy who was your boyfriend	1
With a casual partner	2

B. Did you use any type of contraception?

None	1
The pill and a condom	2
Pill alone	3
Condom alone	4
Withdrawal before ejaculation	5
Another method	6

54. The *last* time you had sexual intercourse ...

A. Who was it with?

With a boy who is (or was) your boyfriend	1	
With a casual partner	2	
I had sexual intercourse only once	3	• *Go to question 55*

B. Did you use any type of contraception?

None	1
The pill and a condom	2
Pill alone	3
Condom alone	4
Withdrawal before ejaculation	5
Another method	6

55. Have you ever been pregnant?

Yes	1
No	2

56. Have you ever had an STD (Sexually Transmitted Disease)?

Yes • *Which one(s)?*______________________________	1
No	2

57. Have you ever had a test for an STD or AIDS?

Yes	1
No	2

58. Have you ever had sexual experiences (touching, caressing, etc.) with a person of the same sex as you (another girl)?

Yes 1
No 2

If you are female • Go to question 74

59. Have you noticed a deepening of your voice?

It has not yet started changing 1
It has barely started changing 2
It has definitely started changing 3
I think it has stopped changing 4

60. Do you have any hair on your face?

I don't have any yet 1
It has just begun to grow 2
I already have quite a bit 3
I think my facial hair has filled in and will remain the same 4

YOUR RELATIONSHIPS WITH GIRLS.

The following questions are about your perceptions with respect to sexuality. Even if you feel you are too young to have had these experiences, we would like to know how you think you would respond in the following situations.

61. For each of the following statements about your sexuality, indicate the degree to which you agree or disagree:

I think I'd be capable of...	**Completely agree**	**Moderately agree**	**Somewhat agree**	**Completely disagree**
A. going out with a girl without feeling obligated to have a sexual relationship with her	1	2	3	4
B. waiting until I feel ready before having a sexual relationship	1	2	3	4
C. choosing when and with whom I have sexual relations	1	2	3	4
D. arranging a means of contraception when I need it	1	2	3	4
E. telling a girl how she can give me pleasure sexually	1	2	3	4
F. speaking about contraception with a girl before having sexual relations with her	1	2	3	4
G. refusing a sexual practice I don't feel comfortable with	1	2	3	4

In a sexual relationship, I think I'd be capable of ...	Completely agree	Moderately agree	Somewhat agree	Completely disagree
H. taking the initiative	1	2	3	4
I. convincing a girl that I should use a condom	1	2	3	4

62. Have you *ever* gone out with a girl? Going out with someone means spending quite intimate moments with her. This can mean for one night or seeing her for several weeks or months.

Yes 1
No .... 2 • *Go to question 73*

63. *During the last 12 months,* have you gone out with one or more girls?

Yes 1
No .... 2 • *Go to question 73*

64. If « yes », *during the last 12 months*, how many times did the following situations occur with one or more of these girls (girlfriend or casual partner)?

	Never	Once	Twice	3 or more times
A. I hurt a girl's feelings (for example, by insulting her in front of people, checking who she went out with, preventing her from seeing her friends, etc.)	0	1	2	3
B. I forced a girl to have sexual contact with me when she didn't want to by pressuring her or harassing her (sexual contact means kissing, petting, touching, sexual intercourse)	0	1	2	3
C. I forced a girl to have sexual contact with me when she didn't want to by threatening to use force or by physically forcing her (sexual contact means kissing, petting, touching, sexual intercourse)	0	1	2	3
D. I threw something at a girl which could have hurt her	0	1	2	3
E. I grabbed a girl and held her by her arms	0	1	2	3
F. I pushed a girl around or shook her	0	1	2	3
G. I slapped a girl	0	1	2	3
H. I hurt a girl by punching her, kicking her, using a weapon, or using an object as a weapon on her	0	1	2	3

In the following questions, voluntarily means with your consent.

65. Have you had sexual intercourse (penetration of the penis) voluntarily?

Yes 1
No . . . . 2 • *Go to question 73*

66. *Since the first time,* with how many different girls have you had sexual intercourse (with penetration) voluntarily?

A. With girls who were your girlfriends? ________ girl(s)
B. With girls who were not your girlfriends? ________ girl(s)

67. How old were you when you had sexual intercourse (penetration) for the first time voluntarily? ________ years old

68. The *first* time you had sexual intercourse ...

A. Who was it with?

With a girl who was your girlfriend 1
With a casual partner 2

B. Did you use any type of contraception?

None 1
The pill and a condom 2
Pill alone 3
Condom alone 4
Withdrawal before ejaculation 5
Another method 6

69. The *last* time you had sexual intercourse ...

A. Who was it with?

With a girl who is (or was) your girlfriend 1
With a casual partner 2
I had sexual intercourse only once . . . . 3 • *Go to question 70*

B. Did you use any type of contraception?

None 1
The pill and a condom 2
Pill alone 3
Condom alone 4
Withdrawal before ejaculation 5
Another method 6

70. Have you ever gotten a girl pregnant?

Yes 1
No 2
Don't know 8

71. Have you ever had an STD (Sexually Transmitted Disease)?

Yes • *Which one(s)?*__________________________ 1
No 2

72. Have you ever had a test for an STD or AIDS?

Yes 1
No 2

73. Have you ever had sexual experiences (touching, caressing, etc.) with a person of the same sex as you (another boy)?

Yes 1
No 2

Physical activity

74. *For the past week* (Monday to Sunday), put a check mark in the days you engaged in the following activities for at least 15 minutes straight. Check "Didn't do any" if this was the case.

- *Physical activities practiced during physical education classes should be indicated in "A" only.*

	Didn't do any	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
A. Physical education classes at school	0	1	2	3	4	5	6	7
B. Cycling (going to school, doing errands, going for a ride, etc.)	0	1	2	3	4	5	6	7
C. In-line skating (rollerblading)	0	1	2	3	4	5	6	7
D. Jogging or running	0	1	2	3	4	5	6	7
E. Physical conditioning (weightlifting, exercise machines, etc.)	0	1	2	3	4	5	6	7
F. Aerobic classes or exercise (other than at school)	0	1	2	3	4	5	6	7
G. Swimming	0	1	2	3	4	5	6	7
H. Badminton, tennis	0	1	2	3	4	5	6	7
I. Karate or judo	0	1	2	3	4	5	6	7
J. Jazz or classical ballet	0	1	2	3	4	5	6	7
K. Dancing (partying with friends)	0	1	2	3	4	5	6	7
L. Gymnastics (on the floor, or using equipment)	0	1	2	3	4	5	6	7
M. Basketball	0	1	2	3	4	5	6	7
N. Volleyball	0	1	2	3	4	5	6	7
O. Soccer	0	1	2	3	4	5	6	7
P. Hockey (ice or ball)	0	1	2	3	4	5	6	7
Q. Snowboarding, downhill skiing	0	1	2	3	4	5	6	7
R. Cross-country skiing	0	1	2	3	4	5	6	7
S. Other(s) • *Name them:*								
1. ____________________	0	1	2	3	4	5	6	7
2. ____________________	0	1	2	3	4	5	6	7
3. ____________________	0	1	2	3	4	5	6	7

75. *During the last week (Monday to Sunday)*, indicate the number of days you engaged in some physical activity, for at least 20 minutes straight, that made you perspire or breathe faster:

7 days (every day)	1
6 days	2
5 days	3
4 days	4
3 days	5
2 days	6
1 day	7
Not one day	8

76. Compared to last year, would you say that you do ...

a lot more sports or physical activity?	1
a little more sports or physical activity?	2
as much sports or physical activity?	3
a little less sports or physical activity?	4
a lot less sports or physical activity?	5

Your other activities

77. *In the past week*, FOR YOUR OWN ENJOYMENT, NOT FOR SCHOOL, did you read ...

	Yes	No
A. a newspaper?	1	2
B. a magazine?	1	2
C. a book?	1	2

78. *In the past week*, did you go to ...

	Yes	No
A. the theatre to see a movie?	1	2
B. a discotheque or bar?	1	2
C. an arcade to play video or computer games?	1	2
D. a music concert?	1	2
E. an arena or stadium to watch a game?	1	2

79. How many hours a day do you usually watch television or videos (don't include video games)?

A. Weekdays : ___________ hours a day

B. Weekends : ___________ hours a day

80. Do you have a computer at home?

Yes 1
No . . . . 2 • *Go to question 82*

81. If « yes », do you use it ...

often? 1
sometimes? 2
never? 3

Your diet

82. *In the past 5 school days,* how many days did you eat or drink something before school began in the morning? Don't count coffee, tea or water.

5 days (every day) 1
3 or 4 days 2
1 or 2 day(s) 3
Never 4

Now let's talk about the whole week, including the weekend.

83. *In the past 7 days,* how many times did you eat supper ...

	Never	**1 or 2 time(s)**	**3 to 5 times**	**6 or 7 times**
A. alone?	1	2	3	4
B. with one or several members of your family?	1	2	3	4
C. with your friends?	1	2	3	4

84. *In the past 7 days,* how many times have you cooked supper for yourself?

Not once . . . . 1 • *Go to question 86*
1 or 2 time(s) 2
3 to 5 times 3
6 or 7 times 4

85. If you have cooked supper for yourself, what did it involve?

	Yes	No
A. Meals already prepared by your parents at home (spaghetti sauce, lasagna, shepherd's pie, etc.)	1	2
B. Store-bought meals that are frozen, canned or easy-to-prepare (such as Kraft Dinner, ravioli, frozen dinners like Stouffer's, etc.)	1	2
C. Meals ordered in from a restaurant (pizza, BBQ chicken, Chinese food, etc.)	1	2
D. Meals you make or cook yourself (sandwiches, hamburgers, steak, etc.)	1	2

86. During supper, whether you eat alone or with someone, do you watch TV or videos?

Always 1
Often 2
Sometimes 3
Never 4

87. *During the past 7 days*, how many times did you ...

	Never	1 or 2 time(s)	3 to 5 times	6 or 7 times
A. eat a meal in a restaurant?	1	2	3	4
B. have a snack in a restaurant?	1	2	3	4
C. have food delivered from a restaurant to your home?	1	2	3	4

88. *In the past 7 days*, how many times did you consume the following foods and beverages?

For each food, mark an • X• in only one column.

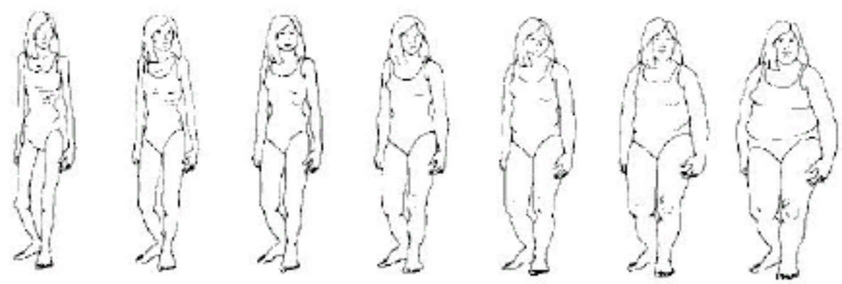
	Not once	By week			By day		
		1-2 time(s)	3-4 times	5-6 times	1-2 time(s)	3-4 times	5 times or more
Milk (as a beverage)	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Raw vegetables and salads	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Cooked vegetables other than potatoes	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Fruit(s) - fresh, canned, frozen or cooked	1 •	2 •	3 •	4 •	5 •	6 •	7 •
Bread, bagel, pita or other types of bread a) White	1 •	2 •	3 •	4 •	5 •	6 •	7 •
b) Whole-wheat (rye, 6-grain, etc.)	1 •	2 •	3 •	4 •	5 •	6 •	7 •

How you perceive yourself

89. This question is about how you perceive your appearance.

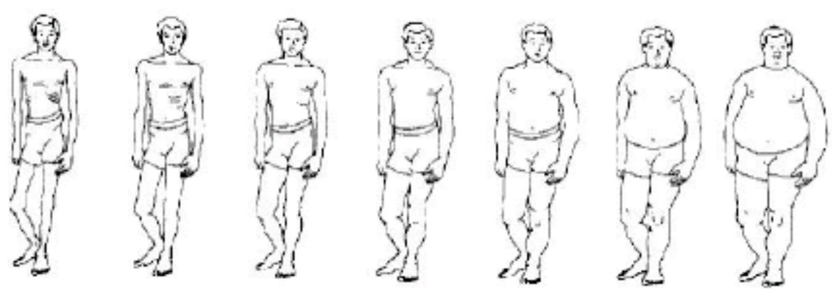
A. Circle the number of the illustration below which best corresponds to *your current appearance.*

Girls



1 • 2 • 3 • 4 • 5 • 6 • 7 •

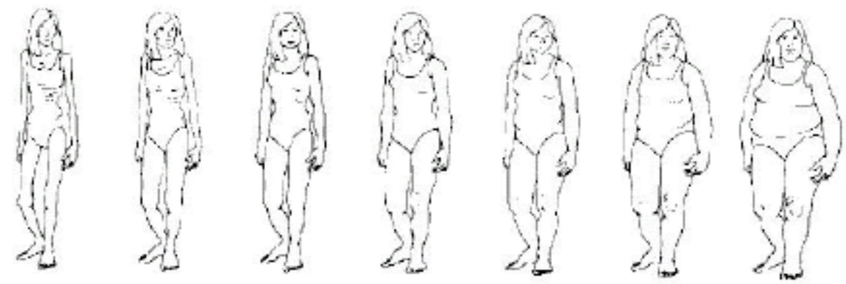
Boys



1 • 2 • 3 • 4 • 5 • 6 • 7 •

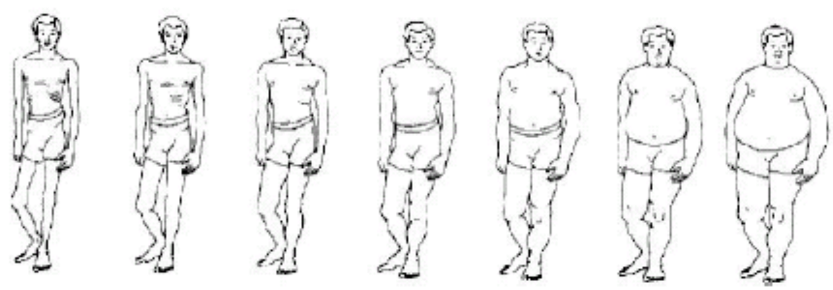
B. Circle the number of the illustration below which best corresponds to *what you'd like to look like*.

Girls



1 • 2 • 3 • 4 • 5 • 6 • 7 •

Boys



1 • 2 • 3 • 4 • 5 • 6 • 7 •

90. Are you currently doing anything about your weight?

I'm trying to lose weight 1
I'm trying to maintain my weight at the same level 2
I'm trying to gain weight 3
I am not doing anything about my weight 4

91. *During the past 6 months,* have you tried to lose weight or maintain your weight?

Yes 1
No . . . . 2 • *Go to question 94*

92. *During the past 6 months*, how many times have you tried to lose weight or maintain your weight?

Once 1
2 or 3 times 2
4 or more times 3

93. In order to lose weight or maintain your current weight, how many times have you tried one or more of the following *in the past 6 months*?

	Often	**A few times**	**Rarely**	**Never**
A. Following a diet (low-calorie, Weight Watchers, nutrition bars or soup diet, etc.)	1	2	3	4
B. Not eating for an entire day	1	2	3	4
C. Taking laxatives (pills that promote bowel movement)	1	2	3	4
D. Taking diet pills (pills that lower appetite)	1	2	3	4
E. Reducing or eliminating sugar or fat in your diet (stop eating candy, dessert, chips, etc.)	1	2	3	4
F. Engaging in intensive training or exercise	1	2	3	4
G. Starting to smoke or going back to smoking	1	2	3	4
H. Skipping meals (breakfast, lunch or supper)	1	2	3	4

94. Have you tried to gain weight *in the past 6 months*?

Yes 1
No2 • *Go to question 97*

95. *During the past 6 months*, how many times did you try to gain weight?

Once	1
2 or 3 times	2
4 or more times	3

96. In order to gain weight, have you tried one or more of the following methods *in the past 6 months?*

	Often	A few times	Rarely	Never
A. Taking dietary supplements to increase muscle mass (creatine, amino acids, weight gain supplements, etc.)	1	2	3	4
B. Taking steroids or other ergogenic products (GH, DHEA...)	1	2	3	4
C. Engaging in extensive training or exercise	1	2	3	4
D. Forcing yourself to eat more	1	2	3	4

97. Do the following people ever go on a diet to lose weight or maintain their weight?

- *Answer "Does not apply" if this person is not present in your life.*

	Yes	No	Does not apply	Don't know
A. Your mother (or adult woman you live with)	1	2	3	8
B. Your father (or adult man you live with)	1	2	3	8
C. One of your brothers or sisters	1	2	3	8
D. One of your friends	1	2	3	8

98. Do the following people ever make negative comments about your weight?

	Yes	No	Does not apply
A. Your mother (or adult woman you live with)	1	2	3
B. Your father (or adult man you live with)	1	2	3
C. One of your brothers or sisters	1	2	3
D. One of your friends	1	2	3
E. Other(s) • *Who?*	1		

99. Do the following people ever encourage or push you to lose weight?

	Yes	No	Does not apply
A. Your mother (or adult woman you live with)	1	2	3
B. Your father (or adult man you live with)	1	2	3
C. One of your brothers or sisters	1	2	3
D. One of your friends	1	2	3
E. Other(s) • *Who?*	1		

Smoking and you

100. Have you ever tried cigarette smoking, even just a few puffs?

Yes 1
No . . . . 2 • *Go to question 106*

101. Have you ever smoked a *whole* cigarette?

Yes 1
No . . . . 2 • *Go to question 106*

102. Have you smoked 100 or more cigarettes *in your life*? (100 cigarettes = 4 packs of 25)

Yes 1
No 2
Don't know 8

103. *During the past 30 days*, did you smoke cigarette, even just a few puffs?

- *Choose only one answer.*

No, I didn't smoke in the last 30 days 1
Yes, every day 2
Yes, almost every day 3
Yes, a few times (a few days) 4

104. *On the days you smoked,* how many cigarettes did you usually smoke?

- *Choose only one answer.*

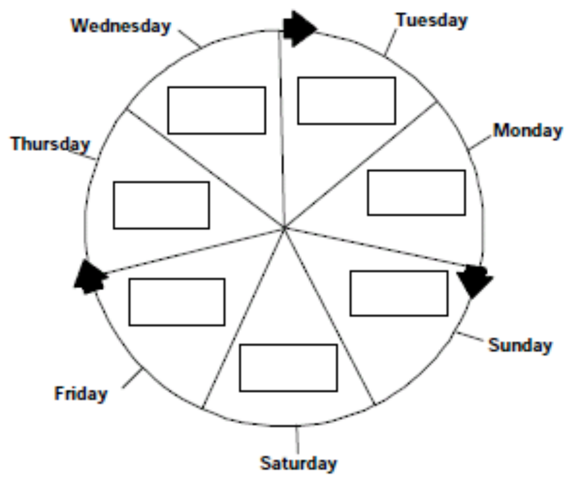
I didn't smoke in the last 30 days	1
Less than one cigarette per day (a few puffs per day) . .	2
1 to 2 cigarette(s) per day	3
3 to 5 cigarettes per day	4
6 to 10 cigarettes per day	5
11 to 20 cigarettes per day	6
More than 20 cigarettes per day	7

105. Thinking back over *the last 7 days,* how many cigarettes did you smoke on each day?

I didn't smoke over the *last 7 days* 97

OR

- *If you smoked, find yesterday on the wheel and follow the arrows to the preceding days, writing the number of cigarettes in the boxes. For the days you didn't smoke, put a "0" in the box.*



106. How many of your friends (boys and girls) smoke cigarettes?

None	1
A few	2
Most	3
All	4
Don't know	8

107. How many of your brothers and sisters smoke cigarettes?

- *Write «0» if you have no brother(s) or sister(s), or if they don't smoke.*

A. I have _______ brother(s) who smoke

B. I have _______ sister (s) who smoke

Your experiences with alcohol and drugs

108. *During the last 12 months*, did you drink alcohol, such as beer, wine or liquor?

Yes 1
No . . . . 2 • *Go to question 113*

109. *During the last 12 months*, how often did you drink alcohol?

Just to taste . . . . 1 • *Go to question 113*
Less than once a month 2
About once a month 3
About once a week 4

The following table might help you answer the next question:

1 drink =	1 small bottle of beer (12 oz or 360 ml) *or* 1 small glass of wine (4-5 oz or 120-150 ml) *or* 1 small shot of hard liquor or spirits (1 to 1 ½ oz. with or without mix)
2 drinks =	1 large bottle of beer (about 25 oz or 750 ml) *or* 1 double shot of hard liquor *or* 1 shot of hard liquor with a beer (beer chaser)

110. *During the last 12 months*, how many drinks did you usually have on each occasion?

Number of drinks: __________

111. How old were you when you had your first drink (alcohol), not counting the times you were just tasting?

__________ years of age

112. *During the past 4 weeks*, how often did you consume alcohol?

I didn't consume any 1
Only on special occasions (birthday, wedding, etc.) 2
Once in a while (not special occasions) 3
I had some every week 4

113. Have you ever used drugs?

Yes 1
No . . . . 2 • *Go to question 117*

114. *During the last 12 months,* how often did you consume each of the following drugs:

	Never or just to try	**Less than once a month**	**About once a month**	**About once a week**
Marijuana or hashish (pot or hash)	1	2	3	4
Glue	1	2	3	4
Cocaine (including crack, snow, crystal)	1	2	3	4
Hallucinogenic (LSD, or "acid", PCP, mescaline, magic mushrooms)	1	2	3	4
Tranquilizers without a prescription or doctor's order (downers, Valium, Librium, Dalmane, Halcion, Ativan, etc.)	1	2	3	4
Other drugs (Ritalin, wake-up pills, speed, Ecstasy, amphetamine, diet pills, etc.) • *Please specify:*	1	2	3	4

115. How old were you when had drugs for the first time?

_______ years of age

116. *During the last 12 months,* did you consume alcohol at the same time as you were consuming drugs?

Yes 1
No 2

117. *During the last 12 months,* has consuming alcohol or drugs ...

	Yes	**No**
A. had a negative effect on your studies?	1	2
B. led to problems with your family or friends?	1	2
C. caused you to injure or wound yourself?	1	2

You and your health

118. In general, would you say that your health is ...

excellent? 1
rather good? 2
not very good? 3

119. Do you ever experience any of the following?

	Rarely/ Never	About once a month	About once a week	About 2 or 3 times a week	Almost every day
A. Headache	1	2	3	4	5
B. Stomach ache	1	2	3	4	5
C. Sore back (back ache)	1	2	3	4	5
D. Insomnia (difficulty sleeping)	1	2	3	4	5
E. Dizziness	1	2	3	4	5
F. Other problem(s) • *Please specify:*	1	2	3	4	5

120. Do you have any of the following chronic health problems that have been diagnosed or confirmed by a doctor or other health professional? A "chronic health problem" means a health problem that lasts or will probably last for 6 months or more.

	Yes	No
A. Food allergies • *Please specify:* 1. ____________ 3. ____________ 2. ____________ 4. ____________	1	2
B. Other allergies (not hay fever)	1	2
C. Respiratory problems other than asthma	1	2
D. Skin problems	1	2
E. Emotional, psychological or nervous problems	1	2
F. Bone or joint problems	1	2
G. Cystic fibrosis	1	2
H. Intestinal problems (Crohn's disease, colitis)	1	2
I. Other digestive problems	1	2
J. Thyroid, liver or kidney problems or disease	1	2
K. Diabetes	1	2
L. Cholesterol or lipid problems	1	2
M. Other chronic health problem(s) • *Please specify:*	1	2

121. Compared to young people your age who are in good health, are you limited in the type or number of activities that you can do because of a chronic physical disease, mental health problem, or any other health problem?

Yes 1
No 2

If « yes », what is the main health problem that limits you?

____

Accidents and injuries

Many young people get hurt or injured at home, on the street, playing sports, fighting, etc. Injuries also include those resulting from poison or burns. Injuries do not include diseases or sickness, such as measles, chicken pox or the flu.

The following questions are about injuries you may have had in the past 12 months.

122. *During the past 12 months,* did you have any injuries that had to be treated by a doctor or nurse?

Yes 1
No . . . . 2 • *Go to question 129*

If you had *more than one injury* in the past 12 months, think only about *the single most serious injury* when answering the following questions.

The most serious injury is the one that took you the most time to recover from.

123. Where were you when this injury happened?

At home (or in someone else's home), for example, on the balcony, in the garage entrance, on a home swing set, exercise apparatus, etc. 01
At school (including the school yard or on school grounds) 02
At a sports facility or field (not a school one) 03
In the street or on a road or highway 04
Other location • *Where?* ______________________________ 96

124. How did it happen?

- *Choose only one answer.*

While riding a bicycle	01
While in-line skating (rollerblading) or skateboarding	02
While playing another sport	03
While in a car, van, truck or on a motorcycle, moped	04
Hit by a car or other vehicle	05
In a fight with someone	06
Tripping or falling on stairs	07
Falling from something (tree, ladder, etc.)	08
Other situation • *Please specify:* ____________________	96

125. Did this most serious injury happen while participating in an organized physical activity or sports league?

Yes	1
No	2

126. Did this most serious injury cause you to miss at least one full day of school or other usual activity?

Yes	1 • *How many days?* __________
No	2

127. What type of injury was it?

- *Choose the answer that best describes your most serious injury.*

Bone was broken, dislocated or out of joint	01
Sprain, strained or pulled muscle	02
Cuts or wounds caused by a sharp object such as knife, glass, bottle, etc.	03
Concussion or other head or neck injury, including whiplash, being knocked out, etc.	04
Bruise(s), black and blue marks, internal bleeding	05
Burn(s)	06
Other • *Please specify:* ____________________	96

128. In what month did this most serious injury happen?

- *Circle the number for only one month.*

January	01	May	05	September	09
February	02	June	06	October	10
March	03	July	07	November	11
April	04	August	08	December	12

129.			
	During the past 12 months, did you use any of the following, as a driver or passenger? • *If "yes", answer to the next column*		Did you wear any safety equipment?
	A. An ATV (all terrain vehicle) 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Helmet** Always . . . . 1 Sometimes . . . . 2 Never 3
	B. Snowmobile 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Helmet** Always . . . . 1 Sometimes . . . . 2 Never 3
	C. SeaDoo 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Lifejacket** Always . . . . 1 Sometimes . . . . 2 Never 3
	D. Moped ("mobylette" - a motorized bicycle - <u>not</u> a scooter) 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Helmet** Always . . . . 1 Sometimes . . . . 2 Never 3
	E. Scooter 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Helmet** Always . . . . 1 Sometimes . . . . 2 Never 3
	F. Motorcycle 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next vehicle*	**Helmet** Always . . . . 1 Sometimes . . . . 2 Never 3
	G. Car 	Yes No Driver 1 2 Passenger 1 2 • *If "no" go to the next question*	**Safety belt** Always . . . . 1 Sometimes . . . . 2 Never 3

130.

During the past 12 months, did you do any of the following activities? • *If "yes", answer to the next column*		Did you wear a helmet?
A. Bicycling 	Yes . . . . 1 No . . . . 2 • *If "no" go to the next activity*	Always . . . . 1 Sometimes . . . . 2 Never 3
B. In-line skating (rollerblading) 	Yes . . . . 1 No . . . . 2 • *If "no" go to the next activity*	Always . . . . 1 Sometimes . . . . 2 Never 3
C. Skateboard 	Yes . . . . 1 No . . . . 2 • *If "no" go to the next question*	Always . . . . 1 Sometimes . . . . 2 Never 3

Health and social services

If you are between 12 and 14 years of age • Go to question 135

131. *During the past 2 weeks,* did you consult one or more of the following people for a physical, emotional or mental health problem:

	Yes	No	Don't know
A. A general practitioner (GP), family doctor?	1	2	8
B. A pediatrician?	1	2	8
C. Another specialist (doctor)? • *Who?*	1	2	8
D. An optometrist or optician (eye doctor)?	1	2	8
E. A nurse?	1	2	8
F. A dentist or orthodontist?	1	2	8
G. A physiotherapist or occupational therapist?	1	2	8
H. An alternative medicine practitioner, such as a chiropractor, acupuncturist, naturopath, osteopath, homeopath?	1	2	8
I. A psychologist?	1	2	8
J. A social worker or any other person offering similar services?	1	2	8
K. Any other person who gives treatment or advice (speech therapist, dietitian, pharmacist)? • *Please specify:*	1	2	8

If you consulted one or more of the people mentioned above, continue with the following questions.

If you answered « no » to all of the above (You didn't consult any of the people mentioned) • Go to question 134

132. What was the main reason you saw or consulted with one of these people the last time?

____

133. Where did this consultation take place?

In the office of the person or at a private clinic 01
In a CLSC 02
In a hospital outpatient clinic or emergency ward 03
In a hospital while hospitalized 04
At a pharmacy 05
At school 06
Other • *Please specify:* ____________________________ 96

134. *During the past 2 weeks*, did you take any of the following medications? (in pill, syrup, capsule form, etc.).

- *Answer for each type of medication.*

A. Medication to reduce pain or fever, such as Tylenol or Aspirin

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

B. Medication for a cold or allergies (pills, syrup...)

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

C. Vitamin(s) or minerals

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

D. Antibiotic

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

E. Medication for respiratory (breathing) problems (such as a medicated pump...)

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

F. Medication to calm you down or help you concentrate better (Ritalin, Ativan, ...)

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

G. Medication other than those mentioned above, including those you don't know the purpose of

Yes • *Please specify which:* ______________________	1
No	2
Don't know	8

135. *Since school began in September*, because of a personal problem, did you meet with one or more of the following people at your school?

	Yes	No
A. Guidance Counsellor	1	2
B. Psychologist or Social Worker	1	2
C. School Nurse	1	2
D. Other • *Please specify:*	1	2

136. Today's date.

				1	9	9	9

Day Month Year

Thank you for your participation!

If you have any comments or suggestions about this questionnaire, please write them in the space provided below:

You may now place your questionnaire in the box and be assured that all your answers will be kept strictly confidential.

Thank you!