Elevated blood pressure and hypertension in South Asian children: A mixed-methods analysis exploring associated factors and behavioural influences

by

Adeleke Fowokan

MPH, University of Essex, 2013

BSc, University of Lagos, 2010

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
Department of Biomedical Physiology and Kinesiology
Faculty of Science

SIMON FRASER UNIVERSITY
Fall 2019

Approval

Name:	**Adeleke Fowokan**
Degree:	**Doctor of Philosophy**
Title:	**Elevated blood pressure and hypertension in South Asian children: A mixed-methods analysis exploring associated factors and behavioural influences**
Examining Committee:	**Chair:** Sam Doesburg Associate Professor
	Scott Lear Senior Supervisor Professor
	Miriam Rosin Supervisor Professor
	Charlotte Waddell Supervisor Professor Faculty of Health Sciences
	Zubin Punthakee Supervisor Associate Professor, McMaster University
	Scott Venners Internal Examiner Associate Professor Faculty of Health Sciences
	Namratha Kandula External Examiner Associate Professor Department of Medicine Feinberg School of Medicine, Northwestern University
Date Defended/Approved:	October 16, 2019

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University

or has conducted the research

c. as a co-investigator, collaborator, or research assistant in a research project approved in advance.

A copy of the approval letter has been filed with the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Abstract

The overarching objective of this PhD thesis was to develop a better understanding of how broad-based (physiological, lifestyle, social and cultural) factors, influence blood pressure (BP) in South Asian children in Canada. This was done using a mixed-methods approach that included: a systematic review which informed the direction of the study; multivariate regression analyses to estimate the correlates of BP and hypertension in South Asian children; receiver operating characteristics curve analysis to estimate the validity of adiposity metrics in estimating adverse risk of hypertension in South Asian children, including the appropriate risk thresholds; and semi-structured qualitative interviews to explore attitudes towards healthy behaviours in South Asian children and their parents. From the systematic review, I identified a range of physiological, social and lifestyle factors that were associated with elevated BP and hypertension in children. These variables were subsequently investigated in a sample of 762 South Asian children in Canada. The results suggested that for these children, physiological variables provided better explanatory capacity regarding the risk of elevated BP and hypertension than social or lifestyle factors. Age, sex, BMI z-score, heart rate and weight accounted for 30% of the variance of sBP z-score, while age, BMI z-score, heart rate and daily fast food intake accounted for 23% of the dBP z-score variance. The prevalence of hypertension was found to be high at 12%. The area under the curve (AUC) values for the adiposity measures for boys and girls ranged from 0.74–0.80, suggesting that the adiposity measures were fair in their ability to estimate hypertension risk. Yet, sex-stratified cut-offs associated with adverse risk of hypertension for South Asian boys and girls suggested that these children might be at high risk of hypertension at levels of adiposity considered normal. Last, my interview findings documented the range of influences on healthy behaviour in South Asian children and their parents including school, peer, social media and cultural dynamics.

Taken as a whole, my thesis provides vital information for healthcare practitioners in identifying and treating at-risk South Asian children, and for public health practitioners and policymakers in informing the development of effective intervention strategies aimed at preventing hypertension and CVD risk in this population.

Keywords: Hypertension; Blood pressure; South Asians; Children; Adiposity; Mixed-methods.

Acknowledgements

Firstly, I will like express my utmost gratitude to my primary supervisor, Dr. Scott Lear for his mentorship and support throughout the PhD as well as my other committee members, Dr. Charlotte Waddell, Dr. Zubin Punthakee and Dr. Miriam Rosin for their insightful input and comments during every stage of the thesis writing process. I could not have imagined a better constellation of erudites to guide me through the PhD process.

Personally, I would like to profoundly thank my family for their love, support and investment throughout my academic journey and life in general. They are the most important people in my cosmos.

Lastly, my sincere gratitude goes to the volunteers, research assistants and community members who participated in this research.

Table of Contents

List of Tables

List of Figures

List of Acronyms

ABPM	Ambulatory blood pressure monitoring
AUC	Area under the curve
BP	Blood pressure
BMI	Body mass index
BIA	Bioelectrical impedance analysis
CI	Confidence interval
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
DEXA	Dual energy x-ray absorptiometry
FFQ	Food Frequency questionnaire
HPA	Hypothalamic pituitary adrenal axis
MET	Metabolic equivalent of task
NHANES III	Third US National Health and Nutrition Examination Survey
NHBPEP	National high blood pressure education program
OR	Odds ratio
ROC	Receiver operating characteristics
RICH-LEGACY	Research in International Cardiovascular Health - Lifestyles, Environments and Genetic Attributes in Children and Youth
REB	Research ethics board
SBP	Systolic blood pressure
WC	Waist circumference
WHO	World health organization
WHtR	Waist to height ratio

Glossary

Acculturation	The process of adopting cultural attributes from another social group
Behavioural risk factors	Risk factors relating to individual lifestyle or actions
Body Mass Index	A ratio of weight to the square of height used to estimate body fatness
Cardiovascular disease	A group of conditions that affects the heart and blood vessels
Diastolic Blood Pressure	The pressure of blood flowing through the arteries following a heartbeat
Growth charts	A reference chart used to follow growth patterns in children over a given time period
Hypertension	A condition in which the pressure of the blood in the arteries is persistently elevated
Physiological risk factors	Risk factors relating to biology
Social risk factors	Risk factors relating to conditions in which people live, attend school, grow, and develop
South Asians	Individuals who have ethnic roots in Bangladesh, India, Nepal, Sri-Lanka, and Pakistan
Systolic blood pressure	The pressure of blood flowing in the arteries when your heart beats
Visceral adipose tissue	Abdominal fat located inside the inner abdominal wall around the internal organs
Waist circumference	A measure used to determine the amount of fat around the abdomen
Waist to height ratio	A ratio of waist circumference to height used to assess central adiposity

Chapter 1.

Introduction

1.1. Background

Hypertension, also known as high blood pressure (BP), is a major contributor to morbidity and mortality from a range of chronic diseases including cardiovascular diseases (CVDs), stroke, and kidney diseases [1]. Globally, hypertension affects about one billion people and is responsible for an estimated 9.4 million deaths annually, including 45% of deaths attributed to CVD and 51% of deaths attributed to stroke [1, 2]. While much of the burden of hypertension has been documented in the adult population, it is now widely established that hypertension in children has reached levels of concern owing to its upsurge over the past few decades [3–5]. Moreover, evidence also suggests high BP in children progresses into adulthood, a phenomenon known as tracking. This underscores the importance of acting early enough to prevent the health consequences attributable to hypertension in adulthood.

1.2. South Asian Ethnicity and Blood Pressure

South Asians represent almost 25% of the world's global population and are the largest visible ethnic minority group in Canada, representing 5% of the total Canadian population and comprising 25% of visible minority groups combined [6,7]. South Asian ethnicity refers to individuals who have ethnic roots in the countries that collectively make up the Indian subcontinent. These countries include Bangladesh, India, Nepal, Sri-Lanka, and Pakistan. Individuals of South Asian origin are widely known to be at increased risk of CVD relative to other ethnic groups [8,9]. These differences in CVD risk extend to South Asian children, in the form of risk factors like hypertension [10,11].

With respect to ethnic differences in BP for South Asian children living in high-income countries, the evidence appears inconsistent, perhaps owing to the limited number of studies that have examined these differences. In the UK, where more ethnic based data on BP in children exist, one review exploring research studies that examined ethnic differences between South Asian children and White British children found mixed results. In one of the studies, higher mean systolic blood pressure (sBP) and diastolic blood pressure (dBP) was reported in South Asian boys and girls compared to White British boys and girls; however, the differences were not statistically significant [12]. In a nationally representative survey, comprising various South Asian subgroups, significantly higher mean sBP and dBP was observed in boys of all the various South Asian subgroups compared to boys in the general population [12]. Conversely, one of the studies reviewed found statistically non-significant lower mean BP in South Asian children compared to White British children [12]. In addition, recent evidence from one UK study that compared BP in British Pakistani and White British children found statistically significant higher sBP in the British Pakistani group [13]. It is not exactly clear what specific factors account for the inconsistencies in studies with conflicting findings, as they varied in the method used in assessing BP, the level of randomization, sample size and in some cases did not provide adequate methodological information. However, taken together, the significant findings showing higher mean BP for South Asian children in two of the studies might be indicative of BP patterns for South Asian children.

While there appear to be inconsistencies in the studies evaluating BP differences for South Asian children, the presence of a disproportionate CVD burden in South Asian adults has been well documented, including for hypertension [14]. Taken as a whole, this evidence, combined with the evidence of BP tracking from childhood to adulthood suggests identifying causes of elevated BP and hypertension in South Asian children may lead to prevention of hypertension in South Asian adults and its associated CVD burden. Consequently, further investigation is warranted into understanding the elevated BP risk in South Asian children, seeking to understand both the distribution and risk correlates.

1.3. Definition of Hypertension in Children

In adults, hypertension is defined using values of sBP and dBP that have been shown in epidemiological studies to be associated with CVD risk [15]. According to the most recent Canadian guidelines, this value corresponds to sBP ≥135mmHg or dBP ≥85mmHg [16]. However, because CVD events rarely manifest in childhood, defining hypertension using CVD outcome data, as is current practice in adults is impractical. Moreover, in growing children, unlike adults, the determination and classification of BP appears to be more complicated as BP varies according to sex, age and height. To address problems in the determination and classification of BP in children, BP reference tables, based on data from a cross section of healthy growing children for both sexes collected at yearly age intervals and across a range of varying heights have been developed [17]. This allows for BP values to be converted to age, sex and height adjusted z-scores, allowing for standardized comparisons between children of similar or different age, sex or height. Based on this, the National High Blood Pressure Education Program (NHBPEP) Working Group on Children, a group made up of clinicians and researchers in the field of paediatrics, defines hypertension as average sBP or dBP greater than the 95th percentile for sex, age and height on three or more occasions [17]. This threshold was identified using evidence from available epidemiological studies and consensus expert opinion from members of the group. Likewise, a category of BP associated with a high risk of developing hypertension known as prehypertension was also established. Prehypertension in children corresponds to average sBP or dBP levels that are greater than or equal to the 90th percentile [17].

1.4. Trends in Hypertension in Children

Although the global prevalence of childhood hypertension is not known due to the lack of a consensus on the definition, rough estimates suggest a rate that ranges from 1% to 5%. In Canada, the prevalence of prehypertension and hypertension in children ages 6–19 years is estimated at 7%, with no known sex differences observed [18]. In terms of ethnicity, the prevalence of hypertension in Canadian-South Asian children is unclear due to scant evidence exploring BP rates by ethnicity in children. One study that compared hypertension rates – using consistent BP definitions – in South Asian children living in Pakistan and White Americans using national survey data found a 12% hypertension prevalence in the South Asian cohort and a 5% hypertension prevalence in the American group, despite a higher body mass index (BMI) level in the latter [11]. It is not clear if the trends in hypertension rates observed in this study reflect hypertension rates in Canadian -South Asian children. A better understanding of the distribution of hypertension in Canadian -South Asian children is therefore important to provide insight into potential disparities.

1.5. Multifactorial Etiology of Elevated BP and Hypertension

It is well known hypertension is a multifactorial disease, occurring as a result of intricate connections between a range of physiological, behavioural and social/environmental factors [19]. In the adult population, the multifactorial etiology of hypertension has been well documented across a range of population groups. Similarly, in children, numerous studies have highlighted associations between variables across different domains (i.e. physiological, behavioural and social), supporting a multifactorial basis for the causes of elevated BP and hypertension. Some of these factors are explored below as a means to contextualize their roles and mechanistic pathways in the development of elevated BP and hypertension in the children population.

1.5.1. Contribution of Physiological Risk Factors to Elevated BP and Hypertension

The role of physiological risk factors in predicting elevated BP and hypertension in children appears to be more widely documented in the research literature than the contributory effect of social or behavioural risk factors. Factors such as genetics, which determine heritability of BP traits are integral to the physiological processes that regulate BP in humans [20]. However, the extent to which genes impact BP is not fully understood as many genetic variance responsible for elevated BP remain unidentified [21]. Genes involved in BP regulatory pathways such as the renin-angiotensin aldosterone system (RAAS), baroreceptor control, renal tubular reabsorption, endothelial ion channels, and the sympathetic nervous system have been suggested as holding promise in improving the understanding of the specific roles of other genes linked to elevated BP [22].

Obesity in children, assessed using a range of adiposity measures has been widely shown to play a contributory role in the development of hypertension in children due to the consistency in association demonstrated by a range of studies [23]. In fact, some experts have suggested the childhood obesity epidemic is significantly responsible for the increase in the prevalence of hypertension in children [24]. One hypothesis for the mechanism linking childhood adiposity to BP is an increase in heart rate seen in obese children, which concomitantly alters BP variability [25]. Alternately, increased adiposity is said to activate the sympathetic nervous system through the mediating effect of high insulin activity in individuals with obesity [25]. Increased SNS activity affects multiple organs leading to the vasoconstriction of blood vessels and increased sodium reabsorption in kidneys, both of which lead to higher BP [26]. Given insulin activity is implicated in the mechanisms involved in BP control in obese children, its role in association with elevated BP in the pediatric population has also been highlighted in epidemiological studies. In a cross-sectional study comprising of children with obesity, children in the highest tertile of insulin resistance were observed to have higher nocturnal sBP, perhaps highlighting the mediating effect of insulin resistance in the development of high BP for obese children [27].

1.5.2. Contribution of Behavioural Risk Factors to Elevated BP and Hypertension

Behavioural factors such as unhealthy diets and physical inactivity have been shown to be associated with elevated BP in the pediatric population [28-32]. Longitudinal evidence from Canadian children examining the relationship between dietary fat and BP reported every additional consumption of 10g of fat resulted in about 0.48 mmHg increase in BP for every year of follow-up, independent of baseline BMI [28]. Findings from a meta-analysis examining the relationship between salt intake and BP in children showed modest reduction in salt consumption resulted in lowered BP rates [29].

The role of physical activity in significantly reducing BP in children has also been documented, such that participation in leisure time activity and sports in children was associated with a reduction in high BP rates [30]. Similarly, negative associations between self-reported physical activity and systolic BP have been reported in adolescent males [31]. In a multi-ethnic study conducted in the US, associations between physical activity and BP were observed in the African- American group but not in the European or Hispanic group [32]. The variations by ethnicity underscore the importance of ethnic specificity when exploring disease risk, as it suggests the etiology of BP might be different by ethnicity. The mechanisms linking physical activity to a reduction in BP are still being explored. However, it has been theorized physical activity may lead to the attenuation in peripheral vascular resistance which may lead to reduction in the action of sympathetic nerves and potentially increase arterial lumen [33]. Additionally, some have also suggested that the anti-hypertensive effects of physical activity occur as a result of its effect on other risk factors including reduction in adiposity [33].

It is relatively unclear how relevant these behavioural factors are in relation to elevated BP in South Asian children as they have not been fully explored in that population. Given behavioural factors are linked with an array of social and cultural beliefs, which are unique across population groups, it is necessary to explore their exact influences in relation to elevated BP. This is especially relevant in South Asian children as studies conducted in the UK have reported low physical activity levels and consumption of higher-fat diets in South Asians relative to their White counterparts [34].

1.5.3. Contribution of Social Risk Factors to Elevated BP and Hypertension

The social conditions in which individuals grow, live and attend school or work significantly affect health outcomes. This is especially true for children and CVD risk-related outcomes [35]. In children, proxy indicators of socioeconomic status such as parental income, parental education, and neighbourhood status have been shown to be associated with elevated BP and hypertension. For example, the Cyprus children's study found low socioeconomic status to be positively predictive of high BP rates [36]. Low socioeconomic status may affect the family's ability to afford nutrient-dense foods and result in the consumption of calorically-dense, low nutrient meals.

The impact of low parental education – a proxy for socioeconomic status – on BP in children has also been reported [37]. The mechanism linking these variables to elevated BP has been suggested to involve the impact of mental health states – including variables such as stress and the resulting physiological implications [38]. Prolonged stress leads to increased sympathetic activity and disturbances to the neuro-endocrine system, which might result in a cascade of hormonal changes that leads to vascular dysfunction [39].

While physiological, behavioural and social factors appear to vary in their specific contribution to the risk of elevated BP and hypertension, mechanistic approaches suggest their contributions to the etiology of BP do not exist in isolation (see Figure 1.1). For example, the social environment can affect lifestyle behaviours related to physical activity and unhealthy diet which in turn can affect physiology. As such, there is a need to develop a clearer understanding of the combined role of these factors to the variance in South Asian children's BP.

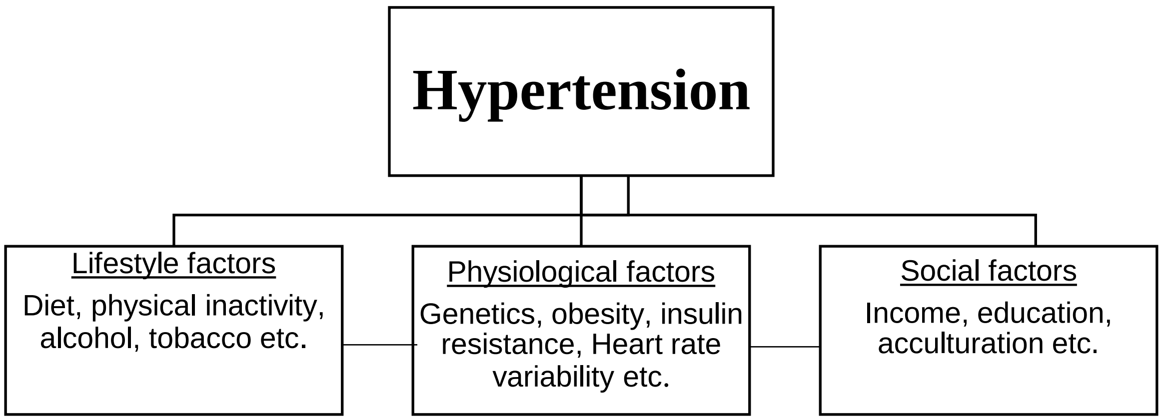


Figure 1.1. Framework showing the relationship between multifactorial variables with hypertension

1.6. Assessment of Obesity in Children

For children, there appears to be a general consensus that partly attributes the increase of hypertension to the concomitant increase in obesity. In fact, childhood obesity has been documented to produce similar metabolic effects as those documented in the adult population [40]. However, some of these metabolic effects, unlike those in adults do not usually manifest until much later in life. While the evidence is clear early obesity predicts hypertension in children, several issues remain regarding how obesity is measured in the paediatric population [41]. Similar to hypertension, because of the gain in weight and height that characterize the growth process in children and their variation by sex, obesity in children is determined using body mass index (BMI) percentiles, developed from normative reference values [42]. These reference values are based on growth charts from a population-based random reference sample that describe normal growth patterns in children. From this, cut-off points defining overweight and obesity have been selected based on a range of criteria (see Table 1.1).

The World Health Organization (WHO), United States Centers for Disease Control (CDC) and the International Obesity Task Force (IOTF) provide three of the most prominent BMI reference values used in determining obesity [41]. However, each varies in their method for determination of obesity cut-off points (Table 1.1). For example, the WHO determines obesity using BMI cut-offs as those who are above two standard deviations above the mean which approximates to the 97.7th percentile. The CDC provides obesity cut-off points similar to those reported by the WHO at the 95th percentile for age and sex. In contrast, the IOTF acknowledging the lack of clarity involving BMI levels associated with health risks in children provide cut-off points by extrapolating back from the obesity BMI levels in adult (BMI≤ 30kg/m2) to yield age and sex specific child cut-off points [41]. Cut-offs for adiposity measures that reflect central adiposity measures like waist circumference (WC) and waist-to-height ratio (WHtR) have also been proposed [43, 44]. These cut-offs are also based on percentile values, however, unlike BMI, the threshold of concern appears unclear owing to huge variations in the cut-offs proposed to identify CVD risk, with some studies proposing values as low as the 51st percentile [45].

It is clear that large variations exist in the cut-off points used to assess cardio-metabolic risk in children, and in some cases ethnic-related variations have been documented [45, 46]. South Asian children have been shown to have a unique phenotype that lends itself to more body fat, specifically visceral fat at similar levels of BMI compared with White children [10]. Therefore it will be important to identify if measures that reflect central adiposity such as WC and WHtR are strongly associated with hypertension. Additionally, an exploration of the appropriateness of established cut-off points for popular adiposity metrics used in children is necessary to determine their validity in determining adverse cardiometabolic risk in South Asian children.

Table 1.1. Overweight and obesity cut-offs for BMI z-scores

World Health Organization	**Center for Disease Control**	**International Obesity Task Force**
Overweight = 1 standard deviation above the mean or 84th percentile Obesity = 2 standard deviations above the mean or 97.7th percentile	Overweight = BMI ≥ 85th percentile but <95th percentile Obesity= BMI at the 95th percentile	Provides age specific values for children 2-18 by extrapolating backwards to determine what BMI value in children corresponds to BMI= 25 for overweight and BMI= 30 for obesity in adults

1.7. Thesis Rationale

In the adult population, a range of studies have explored and documented the trends associated with hypertension distribution and their associated risk factors across a variety of ethnic populations, including ethnic groups that have been shown to be disproportionately affected [47, 48]. In children, however, due to the relatively few studies that have explored risk association for elevated BP and hypertension, the multifactorial etiology of hypertension is less clear. Ethnic groups such as South Asians, which have shown a predisposition to hypertension, have been largely left unexplored. As a result, there remains a gap in the research as to whether risk factors documented in other children such as White children are relevant in South Asian children.

To address the documented burden of elevated BP and hypertension rates in the South Asian child population, a stronger understanding of the multifactorial risk factors for elevated BP and hypertension in this population is needed. This will help inform the identification of modifiable risk factors amenable to interventions, thus possibly preventing the tracking of elevated BP into adulthood. Further, to develop appropriate and effective intervention strategies aimed at addressing the hypertension burden it is important to understand lived experiences including individual beliefs and perspectives regarding healthy behaviours in South Asians. This understanding would in turn allow for the creation of effective health promotion and related preventive interventions that considers relevant socio-cultural factors, which may act as hindrances or facilitators to the adoption of healthy behaviours in the South Asian child population.

1.8. Thesis Objectives

The overarching objective of this mixed methods research is to develop a better understanding of how broad-based (physiological, lifestyle, social and cultural) factors influence BP in South Asian children.

To address the overarching objective, this thesis will be broken down to four linked objectives: 1) to conduct a systematic review of the literature to explore the various factors that predicts elevated BP in children and adolescents (Chapter 2); 2) to explore the associations between physiological, lifestyle and social factors and BP in South Asian children, and to identify the most important aggregate correlates of BP in these children (Chapter 3); 3) to explore the association between adiposity measures with BP and hypertension in South Asian children, to compare the accuracy of these indicators in estimating the risk of hypertension, and to explore the adiposity cut-off values of these indicators associated with adverse risk for hypertension in South Asian children (Chapter 4); and 4) to understand attitudes, perceptions and knowledge about physical activity, diet and CVD risk in children and parents, including potential cultural influences as a means to guide potential intervention studies in this population (Chapter 5).

1.8.1. Rationale for Chapter 2

Research evidence from different populations globally has documented an increase in the prevalence of hypertension in children [3-5]. In American children aged 8-17 years, for example, the prevalence of prehypertension and hypertension increased from 15.8% to 19.2% in boys and 8.2% to 12.6% in girls between 1999 and 2008 [5]. Yet despite the contribution of the obesity epidemic to hypertension in children [23], little is known about the contributory effect of other factors. The pathophysiology of elevated BP has been shown to be complex, and has its roots in a wide range of risk factors [19]. Thus, a systematic review of the research literature that seeks to explore and document the evidence is needed to inform both healthcare and public health practice, as well as new research. Moreover, identifying the broad array of risk factors for elevated BP and hypertension in the child population is an integral first step in informing the focus of this dissertation as it will broadly inform knowledge of the etiology of high BP in childhood. This in turn will help focus the thesis by identifying relevant risk factors whose associations with elevated BP and hypertension in South Asian children need to be explored.

1.8.2. Rationale for Chapter 3

In South Asian children, studies have highlighted increased prevalence of hypertension and higher average levels of BP relative to other ethnic groups [11,13]. However, it is relatively unclear what factors are responsible for this. Given that the etiology of elevated BP and hypertension is multifactorial [19], this understanding will require an exploration of multiple risk factors. Using the information from the systematic review of elevated BP and hypertension in children conducted in Chapter 2, I will select a range of physiological, social and behavioural risk factors in order to explore their links with elevated BP and hypertension in the South Asian children population. This will help provide more robust knowledge on risk factors that need to be targeted with interventions as a means to address the burden of elevated BP and hypertension in South Asian children.

1.8.3. Rationale for Chapter 4

The contributory role of obesity in children to elevated BP and hypertension has been widely documented. Childhood obesity alters the metabolic profile in a similar way as seen in adults, possibly resulting in increased risk factors for CVD including hypertension [40]. Studies conducted in children have shown that compared to those with normal weight, obese children have a higher risk of developing hypertension [49]. While the links between obesity and hypertension appear clear, several issues remain regarding how obesity is defined including the thresholds associated with CVD risk in children. For example, the WHO, CDC and IOTF all differ in the BMI cut-offs used in determining obesity [41]. For metrics like WC and WHtR, a range of cut-offs from the 51st percentile to the 95th percentile have been outlined by different studies as the threshold associated with adverse CVD risk in the children population. Given the adiposity phenotype of South Asian children which is characterized by higher body fat at similar levels of BMI when compared to White children [10], it remains unclear if metrics like BMI, WC and WHtR are valid for use in estimating hypertension risk in South Asian children, and if valid, what thresholds of these adiposity metrics are associated with adverse risk for CVD risk factors. This understanding will potentially enable the easier identification of at-risk South Asian children in primary care, ensuring they are offered appropriate clinical interventions early, as well as informing preventive public health interventions.

1.8.4. Rationale for Chapter 5

The disproportionately higher risk for CVD in the South Asian population has been established [14]. Moreover, studies have also reported lower levels of physical activity and limited knowledge about CVD-related behaviours [34, 50]. Several intervention studies have been targeted towards this population in different countries with varying results [51]. However, it is unclear how effective these interventions are in the long-term as they appear to adopt generalized intervention approaches. As well, translating interventions that have shown to be effective in White populations to South Asians may be incongruent given cultural differences between the two groups [52]. For interventions to be sustained long term, an approach that is rooted in cultural understanding will be necessary. Moreover, given the elevated risk of CVD-related factors found in South Asian children, and the influence of parents on child behaviours, understanding the combined perspective of both children and their parents will be vital [13]. Utilizing a qualitative approach, this chapter will provide insights into knowledge and perspectives of South Asian children and their parents regarding healthy behaviours implicated in cardiovascular health. This in-turn will provide valuable information that will guide the development of interventions that consider the unique socio-cultural lens of South Asian families.

1.9. References

1. WHO. *A Global Brief on Hypertension*.; 2013. doi:10.1136/bmj.1.4815.882-a

2. Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2224-2260. doi:10.1016/S0140-6736(12)61766-8

3. Xi B, Liang Y, Mi J. Hypertension trends in Chinese children in the national surveys, 1993 to 2009. *Int J Cardiol*. 2013;165(3):577-579. doi:10.1016/j.ijcard.2012.09.032

4. Lee CG. The Emerging Epidemic of Hypertension in Asian Children and Adolescents. *Curr Hypertens Rep*. 2014;16(12):1-9. doi:10.1007/s11906-014-0495-z

5. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: The NHANES experience 1988-2008. *Hypertension*. 2013;62(2):247-254. doi:10.1161/HYPERTENSIONAHA.111.00831

6. Population Reference Bureau. 2017 World Population Data Sheet. PRB's 2017 World Population Data Sheet.

7. Statistics Canada. Immigration and Ethnocultural Diversity in Canada. National Household Survey, 2011. National Household Survey, 2011. doi:99-010-X2011001

8. Lear SA, Humphries KH, Kohli S, Chockalingam A, Frohlich JJ, Birmingham CL. Visceral adipose tissue accumulation differs according to ethnic background: Results of the Multicultural Community Health Assessment Trial (M-CHAT). *Am J Clin Nutr*. 2007;86(2):353-359.

9. Anand SS, Yusuf S, Vuksan V, et al. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE). *Lancet*. 2000;356(9226):279-284. doi:10.1016/S0140-6736(00)02502-2

10. J Eyre EL, Duncan MJ, Nevill A. South Asian Children Have Increased Body Fat in Comparison to White Children at the Same Body Mass Index. *Children.* 2017; 4(11); 102 doi:10.3390/children4110102

11. Jafar TH, Islam M, Poulter N, et al. Children in South Asia have higher body mass-adjusted blood pressure levels than white children in the United States: a comparative study. *Circulation*. 2005;111(10):1291-1297. doi:10.1161/01.CIR.0000157699.87728.F1

12. Agyemang C, Bhopal R, Bruijnzeels M. Do variations in blood pressures of South Asian, African and Chinese descent children reflect those of the adult populations in the UK? A review of cross-sectional data. *J Hum Hypertens*. 2004;18(4):229-237. doi:10.1038/sj.jhh.1001658

13. Henderson EJ, Jones CHD, Hornby-Turner YC, Pollard TM. Adiposity and blood pressure in 7- to 11-year-old children: Comparison of British Pakistani and white British children, and of British Pakistani children of migrant and British-born mothers. *Am J Hum Biol*. 2011;23(5):710-716. doi:10.1002/ajhb.21204

14. Rana A, Anand SS, Lear SA, de Souza RJ, Kandasamy S. Cardiovascular risk among South Asians living in Canada: a systematic review and meta-analysis. *C Open*. 2014;2(3):E183-E191. doi:10.9778/cmajo.20130064

15. Daniels SR. How to Define Hypertension in Children and Adolescents Running title: Daniels; How to Define Hypertension in Children. 2017:350-351. doi:10.1161/CIRCULATIONAHA.115.020531

16. Nerenberg KA, Zarnke KB, Leung AA, Dasgupta K, Butalia S, McBrien K, Harris KC, Nakhla M, Cloutier L, Gelfer M, Lamarre-Cliche M. Hypertension Canada's 2018 guidelines for diagnosis, risk assessment, prevention, and treatment of hypertension in adults and children. *Canadian Journal of Cardiology*. 2018; 34(5):506-25.

17. National High Blood Pressure Education Program Working Group on High Blood. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004;114(2 Suppl 4th Report):555-576. doi:10.1542/peds.114.2.S2.555

18. Statistics CANADA. Blood pressure of children and youth, 2012 to 2015. https://www150.statcan.gc.ca/n1/pub/82-625-x/2016001/article/14659-eng.htm. Published 2016.

19. Waeber B, Brunner HR, Joint National Committee in the US (JNC-VI), World Health Organization - International Society of Hypertension (WHO-ISH). The multifactorial nature of hypertension: the greatest challenge for its treatment? *J Hypertens Suppl*. 2001;19(3):S9-16. http://www.ncbi.nlm.nih.gov/pubmed/11713851. Accessed March 21, 2019.

20. Ehret GB, Caulfield MJ. Genes for blood pressure: an opportunity to understand hypertension. *Eur Heart J*. 2013;34(13):951-961. doi:10.1093/eurheartj/ehs455

21. Taal HR, Verwoert GC, Demirkan A, et al. Genome-wide profiling of blood pressure in adults and children. *Hypertens (Dallas, Tex 1979)*. 2012;59(2):241-247. doi:10.1161/HYPERTENSIONAHA.111.179481

22. Raj M. Essential hypertension in adolescents and children: Recent advances in causative mechanisms. *Indian J Endocrinol Metab*. 2011;15(8):367. doi:10.4103/2230-8210.86981

23. Wühl E. Hypertension in childhood obesity. *Acta Paediatr*. 2019;108(1):37-43. doi:10.1111/apa.14551

24. Falkner B, Gidding S. Childhood obesity and blood pressure: back to the future? *Hypertens (Dallas, Tex 1979)*. 2011;58(5):754-755. doi:10.1161/HYPERTENSIONAHA.111.180430

25. Sorof J, Daniels S. Obesity hypertension in children: A problem of epidemic proportions. *Hypertension*. 2002;40(4):441-447. doi:10.1161/01.HYP.0000032940.33466.12

26. Brady TM. Obesity-Related Hypertension in Children. *Front Pediatr*. 2017;5(September):1-7. doi:10.3389/fped.2017.00197

27 Lurbe E, Torro I, Aguilar F, Alvarez J, Alcon J, Pascual JM, Redon J. Added impact of obesity and insulin resistance in nocturnal blood pressure elevation in children and adolescents. *Hypertension*. 2008;51(3): 635-41.

28. Setayeshgar S, Ekwaru JP, Maximova K, et al. Dietary intake and prospective changes in cardiometabolic risk factors in children and youth. *Appl Physiol Nutr Metab*. 2017;42(1):39-45. doi:10.1139/apnm-2016-0215

29. He FJ, MacGregor GA. Importance of Salt in Determining Blood Pressure in Children. *Hypertension*. 2006;48(5):861-869. doi:10.1161/01.hyp.0000245672.27270.4a

30. Gaya AR, Silva P, Martins C, Gaya A, Ribeiro JC, Mota J. Association of leisure time physical activity and sports competition activities with high blood pressure levels: Study carried out in a sample of portuguese children and adolescents. *Child Care Health Dev*. 2011;37(3):329-334. doi:10.1111/j.1365-2214.2010.01179.x

31. Shi Y, De Groh M, Morrison H. Increasing blood pressure and its associated factors in Canadian children and adolescents from the Canadian health measures survey. *BMC Public Health*. 2012;12(1):1. doi:10.1186/1471-2458-12-388

32. Casazza K, Klimentidis YC, Allison DB, Dulin-Keita A, Willig AL, Fernandez JR. Genetic admixture, social–behavioural factors and body composition are associated with blood pressure differently by racial–ethnic group among children. *J Hum Hypertens*. 2011;26(2):98-107. doi:10.1038/jhh.2010.130

33. Hamer M. The Anti-Hypertensive Effects of Exercise. *Sport Med*. 2006;36(2):109-116. doi:10.2165/00007256-200636020-00002

34. Fischbacher CM, Hunt S, Alexander L. How physically active are South Asians in the United Kingdom? A literature review. *J Public Health (Bangkok)*. 2004;26(3):250-258. doi:10.1093/pubmed/fdh158

35. Barr DA, Blair I V., Davey-Smith G, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease. *Circulation*. 2015;132(9):873-898. doi:10.1161/cir.0000000000000228

36. Lazarou C, Panagiotakos DB, Matalas A-L. Lifestyle factors are determinants of children’s blood pressure levels: the CYKIDS study. *J Hum Hypertens*. 2009;23(7):456-463. doi:10.1038/jhh.2008.151

37. Simonetti GD, Schwertz R, Klett M, Hoffmann GF, Schaefer F, Wühl E. Determinants of blood pressure in preschool children: the role of parental

smoking. *Circulation*. 2011;123(3):292-298. doi:10.1161/CIRCULATIONAHA.110.958769

38. Havranek EP, Mujahid MS, Barr DA, et al. Social Determinants of Risk and Outcomes for Cardiovascular Disease. *Circulation*. 2015;132(9):873-898. doi:10.1161/CIR.0000000000000228

39. Steptoe A, Kivimäki M. Stress and Cardiovascular Disease: An Update on Current Knowledge. *Ssrn*. 2013;5. doi:10.1146/annurev-publhealth-031912-114452

40. Abrams P, Levitt Katz LE. Metabolic effects of obesity causing disease in childhood. *Curr Opin Endocrinol Diabetes Obes*. 2011;18(1):23-27. doi:10.1097/MED.0b013e3283424b37

41. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes*. 2010;5:265-273. doi:10.3109/17477160903268282

42. Must A, Anderson SE. Body mass index in children and adolescents: considerations for population-based applications. *Int J Obes*. 2006;30(4):590-594. doi:10.1038/sj.ijo.0803300

43. Campagnolo PDB, Hoffman DJ, Vitolo MR. Waist-to-height ratio as a screening tool for children with risk factors for cardiovascular disease. *Ann Hum Biol*. 2011;38(3):265-270. doi:10.3109/03014460.2010.526147

44. Moreno L, Pineda I, Rodriguez G, … JF-A, 2002 undefined. Waist circumference for the screening of the metabolic syndrome in children. *Wiley Online Libr*. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1651-2227.2002.tb02825.x. Accessed March 27, 2019.

45. Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. *Pediatrics*. 2004;114(2):e198-205. http://www.ncbi.nlm.nih.gov/pubmed/15286257. Accessed January 20, 2017.

46. Khadilkar A, Ekbote V, Chiplonkar S, et al. Waist circumference percentiles in 2-18 year old indian children. *J Pediatr*. 2014;164(6):1358-1362.e2. doi:10.1016/j.jpeds.2014.02.018

47. Kearney PM, Whelton M, Reynolds K, Whelton PK, He J. Worldwide prevalence of hypertension: a systematic review. *J Hypertens*. 2004;22(1):11-19. http://www.ncbi.nlm.nih.gov/pubmed/15106785. Accessed March 28, 2019.

48. Anchala R, Kannuri NK, Pant H, et al. Hypertension in India. *J Hypertens*. 2014;32(6):1170-1177. doi:10.1097/HJH.0000000000000146

49. Koebnick C, Black MH, Wu J, et al. High Blood Pressure in Overweight and Obese Youth: Implications for Screening. *J Clin Hypertens*. 2013;15(11):793-805. doi:10.1111/jch.12199

50. Owen CG, Nightingale CM, Rudnicka AR, Cook DG, Ekelund U, Whincup PH. Ethnic and gender differences in physical activity levels among 9–10-year-old children of white European, South Asian and African–Caribbean origin: the Child Heart Health Study in England (CHASE Study). *Int J Epidemiol*. 2009;38(4):1082-1093. doi:10.1093/ije/dyp176

51 Chapman J, Qureshi N, Kai J. Effectiveness of physical activity and dietary interventions in South Asian populations: A systematic review. *Br J Gen Pract*. 2013;63(607). doi:10.3399/bjgp13X663064

52 Patel M, Phillips-Caesar E, Boutin-Foster C. Attitudes and beliefs regarding cardiovascular risk factors among Bangladeshi immigrants in the US. Journal of immigrant and minority health. 2014;16(5): 994-1000.

Chapter 2.

Correlates of elevated blood pressure in healthy children: a systematic review[1]

2.1. Introduction

Cardiovascular diseases (CVDs) exert a significant toll on global morbidity and mortality [1, 2]. One of the most important risk factors for CVDs is hypertension or high blood pressure (BP) [2]. According to the World Health Organization (WHO), high BP accounts for 45% of all deaths due to heart diseases, and 51% of deaths due to stroke. In 2010, the number of combined deaths worldwide attributable to high BP was estimated at 9.4 million [2]. Although most of the burden of hypertension is attributed to adults, evidence suggests that the problem may have its origins in childhood [3].

In children, pre-hypertension is defined as systolic BP (sBP) or diastolic BP (dBP) that is between the 90th and 95th percentile, while hypertension is defined as sBP or dBP at the 95th percentile for age, sex and height on three or more occasions [3]. A large body of research evidence from different populations globally has demonstrated an increase in the prevalence of hypertension in children [4–7]. For example, an American study using a large nationally representative survey of children aged 8–17 years found that the prevalence of pre-hypertension and hypertension increased from 15.8% to 19.2% in boys and 8.2% to 12.6% in girls between 1999 and 2008 [7]. Similarly, a large-scale nationally-representative survey of Chinese children aged 6–17 years estimated that hypertension rose from 7.6% to 13.8% between 1993 and 2009 in both sexes [6]. In addition to the increased prevalence of hypertension, one recent meta-analysis demonstrated evidence of BP tracking from childhood to adulthood [8]. This research evidence has important clinical and public health implications for addressing the disease burden attributable to hypertension, as it suggests interventions aimed at addressing hypertension should begin in childhood to alter disease progression into adulthood.

[1] Fowokan AO, Sakakibara BM, Onsel N, Punthakee Z, Waddell C, Rosin M, Lear SA. Correlates of elevated blood pressure in healthy children: a systematic review. *Clinical Obesity.* 2018; 8(5):366-81

While much of the burden of hypertension in children is associated with increases in the prevalence of childhood obesity [9, 10], the pathophysiology of hypertension is complex, originating from a broad array of factors (many of which are modifiable) across multiple health domains (i.e., physiological, behavioural and social), some of which include but are not limited to the increased prevalence of childhood adiposity [11]. Thus, developing an understanding of the etiology of hypertension in children will contribute to the development of intervention strategies targeting such modifiable factors.

Although systematic reviews on children have been conducted to look at potential correlates [12, 13], these reviews have been limited in scope, focusing on a single correlate of BP. Given the variation in the number of risk factors for hypertension, a review that examines the research evidence and organizes the risk factors more comprehensively and systematically is needed to inform public health and healthcare practice and policy. To this end, we aimed to conduct a systematic review of the literature to identify the correlates of elevated BP, including pre-hypertension and hypertension, in children aged 0–18 years.

2.2. Methods

2.2.1. Search strategy and selection

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Relevant studies for this systematic review were identified by conducting a computerized literature search using MEDLINE, the Cumulative Index to Nursing and Allied Health Literature (CINAHL) and the Evidence-Based Medicine Reviews (EBMR) multi-file database from January 2000 to June 2017. Search terms for the identification of relevant studies were developed in consultation with a librarian and research specialists in the field of CVD risk factor research. Using both Medical Subheadings (MeSH) and key words (see Appendix 1, Supporting Information), we searched for articles using the following inclusion criteria:

1. All relevant studies published from the year 2000 onwards (as the preponderance of research evidence on risk factors for BP in children were published

within this time period) in children (≤18 years of age) with elevated BP, pre-hypertension or hypertension as an outcome (primary or secondary);

2. Studies that identified at least one correlate of high BP in children, and adjusted for potential confounders (or utilized multi-variate modelling);

3. Studies that clearly defined the device used in measuring BP, and the cut-off used to diagnose hypertension or pre-hypertension;

4. Studies published in English (studies published in other languages were excluded due to the lack of technical expertise in accurately interpreting languages other than English; however, preliminary abstract review of these studies presented no new risk factors apart from those already identified in this review);

5. Studies published as full manuscripts; works in progress, conference abstracts, incomplete papers were excluded; reviews, rather than original, data were also excluded, but reference lists from reviews were hand-searched for relevant articles; and

6. Studies conducted in a general child population (studies including children with a specific health condition alone were excluded, for example, pre-term birth, children who were overweight or obese, children born with low birthweight).

After detailed searches were conducted using the search strategy, as described in Fig. 2.1, one investigator (A.F.) screened the titles, then the abstracts to arrive at a list of articles for a detailed full-text review. Full-text review for eligibility was then conducted independently by two investigators (A.F. and N.O. – a PhD researcher). Disagreements were resolved by discussion, or by consulting a third author (B.M.S. – a postdoctoral researcher). This systematic review was registered with PROSPERO (Registration number: CRD42017054876).

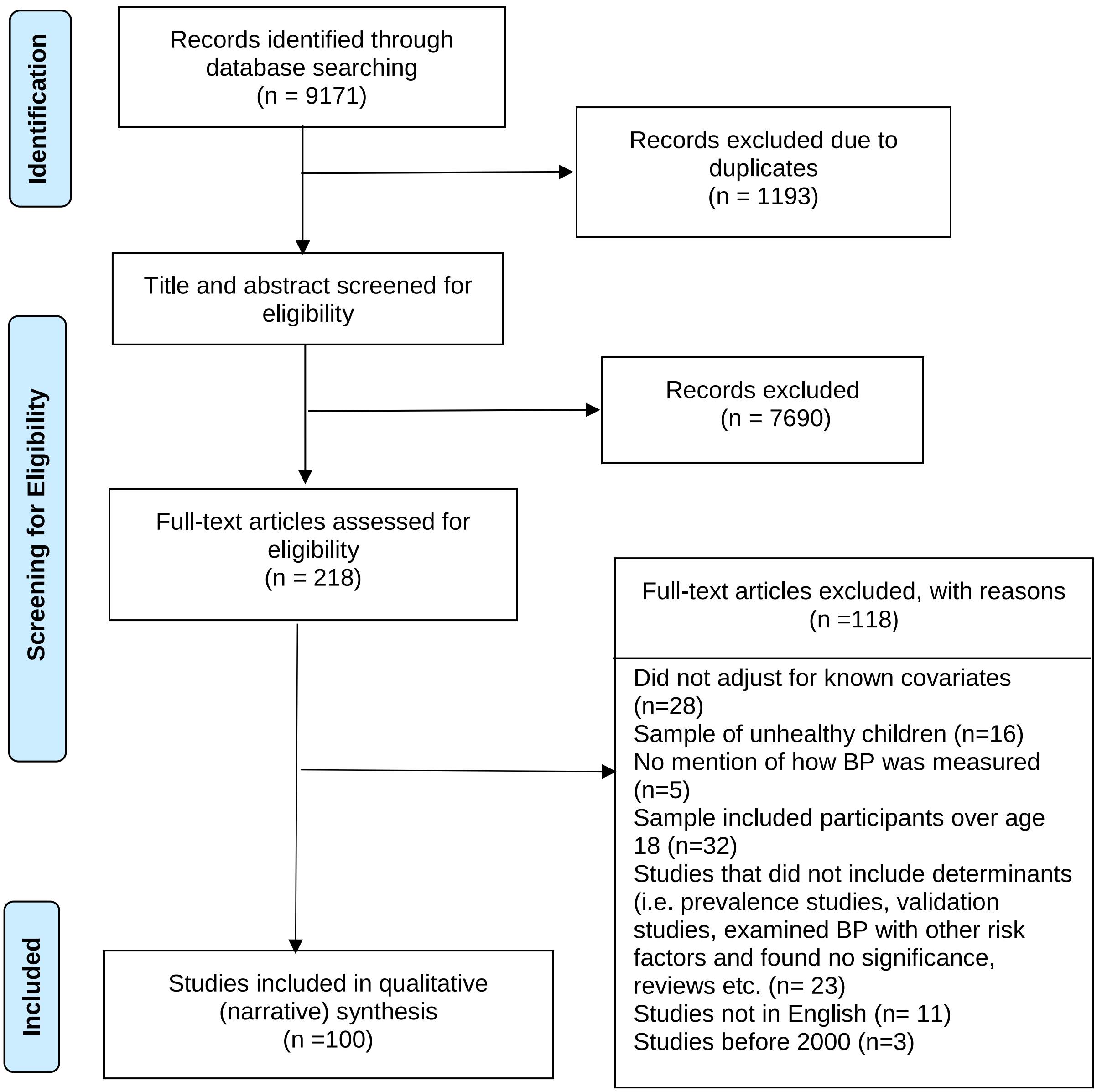


Figure 2.1. Adapted PRISMA DIAGRAM

2.2.2. Risk of Bias Assessment

Using a modified version of the National Institute of Health (NIH) quality assessment tool for observational studies [14], we provided risk of bias assessment scores on each of the included studies. The NIH tool grades observational studies on several important criteria including a clearly stated research objective, sample size justification, validity of exposure and outcome measures and the inclusion of potential confounding variables in statistical analyses. A complete list of the 14 NIH criteria is presented in Table 2.1. Studies that did not clearly address the specific criteria in the NIH tool were given a zero score, while studies that addressed the criteria were scored a single point for each of the 14 items. Each study was then scored according to the total points received for each criteria addressed over the total number of applicable items in the NIH tool (see Table 2.2). Because the NIH tool was created to cover both longitudinal and cross-sectional studies, in certain cases the not-applicable (NA) code was used if the investigator thought the specified criterion was incongruent with the study design adopted (for example, “was loss to follow up after baseline 20% or less” in a study whose design was cross sectional not longitudinal). To reduce investigator bias, this evaluation was also carried out independently by A.O.F. and N.O. Disagreements were resolved by discussion, or by consulting a third author (B.M.S.).

Table 2.1. NIH quality assessment checklist for observational cohort and cross-sectional Studies

Criteria
1. Was the research question or objective in this paper clearly stated?
2. Was the study population clearly specified and defined?
3. Was the participation rate of eligible persons at least 50%?
4. Were all the subjects selected or recruited from the same or similar populations (including the same time)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?
5. Was a sample size justification, power description, or variance and effect estimates provided?
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?

10. Was the exposure(s) assessed more than once over time?

11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?

12. Were the outcome assessors blinded to the exposure status of participants?

13. Was loss to follow-up after baseline 20% or less?

14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?

Table 2.2. Results of the quality assessment of the papers included in this review

Study Reference	Checklist items														Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Adair et al[15]	+	+	+	+	-	+	+	+	-	-	+	NA	-	+	9/13
Aeberli et al[16]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11
Akis et al[17]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Barba et al[18]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Barba et al[19]	+	-	+	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Bergel et al[20]	+	+	+	+	+	+	+	-	+	-	+	NA	+	+	11/13
Bergmann et al[21]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11
Blake et al[22]	+	+	-	+	-	+	+	+	+	+	+	NA	-	-	9/13
Bohlke et al[23]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11
Bonamy et al[24]	+	+	+	-	-	-	-	+	+	NA	+	NA	NA	-	6/11
Brady and Matthews[25]	+	+	-	+	-	-	+	+	+	NA	+	NA	NA	+	8/11
Brambilla et al[26]	+	+	-	+	-	+	+	+	+	+	+	NA	-	+	10/13
Brion et al[27]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Burgos et al[28]	+	+	-	+	+	-	-	+	+	NA	-	NA	NA	-	6/11
Chen et al[29]	+	+	-	+	-	-	-	+	+	+	+	NA	-	+	8/13
Chirico et al[30]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Cho et al[31]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Christofaro et al[32]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	+	8/11
Clark et al[33]	+	+	+	+	+	+	+	-	+	NA	+	NA	NA	+	10/11
Colin-Ramirez et al[34]	+	+	+	+	-	-	-	+	+	NA	-	NA	NA	-	6/11
Correia-Costa et al[35]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Dasgupta et al[36]	+	+	+	+	-	+	+	+	+	+	+	NA	+	+	12/13
De Onis et al[37]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Dinc et al[38]	+	+	-	+	+	-	-	+	+	NA	-	NA	NA	+	7/11

Study Reference	Checklist items														Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Dong et al[39]	+	+	+	+	-	-	-	-	+	NA	+	NA	NA	+	7/11
Dong et al[40]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Dulskiene et al[41]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Eisenmann et al[42]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Farajian et al[43]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Flores-Huerta et al[44]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Gaya et al[45]	+	+	-	+	-	+	-	+	+	NA	+	NA	NA	-	7/11
Gillman et al[46]	+	+	+	+	-	+	+	+	+	+	+	NA	-	+	11/13
Goel at al[47]	+	+	+	+	+	-	-	+	+	NA	-	NA	NA	-	7/11
Goharian et al [48]	+	+	-	+	+	+	-	+	+	-	+	NA	-	+	9/13
Going et al[49]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Goosby et al[50]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Hacke & Weisser[51]	+	+	+	+	-	-	-	-	+	NA	+	NA	NA	+	7/11
He et al[52]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	+	6/11
Hemachandra et al[53]	+	+	+	+	-	+	+	+	+	+	+	NA	+	-	11/13
Huang et al[54]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Huntington-Moskos et al[55]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11
Jago et al[56]	+	+	-	+	-	+	+	+	+	+	+	NA	-	+	10/13
Jones et al[57]	+	+	+	+	-	+	+	+	+	+	+	NA	-	-	10/13
Kaczmarek et al[58]	+	+	+	+	+	-	-	+	+	NA	+	NA	NA	-	8/11
Kagura et al[59]	+	+	-	+	-	+	+	+	+	+	+	NA	-	+	10/13
Katona et al[60]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Khoury et al[61]	+	+	-	+	-	+	+	+	+	+	+	+	+	-	11/14
Klakk et al[62]	+	+	+	+	-	+	+	+	+	+	+	NA	-	+	11/13
Kuciene et al[63]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11

Study Reference	Checklist items														Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Kwok et al[64]	+	+	+	+	-	+	+	-	+	+	+	NA	+	+	11/13
Landazuri et al[65]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Lazarou et al[66]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	+	6/11
Le-Ha et al[67]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Leung et al[68]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Lim et al[69]	+	+	+	+	-	+	+	+	+	-	+	NA	-	+	10/13
Lurbe et al[70]	+	+	-	+	-	+	+	+	+	NA	+	NA	NA	-	8/11
Maximova et al[71]	+	+	+	+	-	+	+	+	+	+	+	NA	-	+	11/13
Mbolla et al[72]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11
McGrath et al[73]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Mirzaei et al[74]	+	+	-	+	-	+	+	+	+	+	+	NA	-	-	9/13
Moore et al[75]	+	+	+	+	-	-	-	+	+	NA	-	NA	NA	-	6/11
Moraes et al[76]	+	+	-	-	-	+	+	+	+	+	+	NA	-	+	9/13
Moser et al[77]	+	+	+	+	+	-	-	+	+	NA	+	NA	NA	-	8/11
Mu et al[78]	+	+	-	+	-	+	+	-	+	-	+	NA	+	+	9/13
Munthali et al[79]	+	+	+	+	-	+	+	+	+	+	+	NA	+	-	11/13
Musa et al[80]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Na young Kim et al[81]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Narang et al[82]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Nayoung Kim et al[83]	+	+	-	+	-	+	+	+	-	+	-	NA	-	+	8/13
Normia et al[84]	+	+	-	+	-	+	+	+	+	+	+	NA	-	-	9/13
Nowson et al[85]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Nur et al[86]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	+	6/11
Odunaiya et al[87]	+	+	-	+	+	-	-	+	+	NA	-	NA	NA	-	6/11
Peach et al[88]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	+	6/11
Polderman et al[89]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Queiroz et al[90]	+	+	-	+	+	-	-	+	+	NA	+	NA	NA	-	7/11

Study Reference	Checklist items														Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Ramos-Arellano et al[91]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	-	5/11
Relton et al[92]	+	+	-	+	-	+	+	+	+	NA	+	NA	NA	+	9/11
Ribeiro et al[93]	+	+	+	+	+	-	-	+	+	NA	+	NA	NA	+	9/11
Savva et al[94]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Sesso and Franco[95]	+	+	+	+	-	-	-	+	-	NA	+	NA	NA	-	6/11
Sesso et al[96]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Setayeshgar et al[97]	+	+	-	+	-	+	+	+	+	-	+	NA	-	-	8/11
Sharp et al[98]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	+	7/11
Shirasawa et al[99]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Simonetti et al[100]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Taal et al[101]	+	+	-	+	-	+	+	+	+	-	+	NA	-	+	9/13
Taine et al[102]	+	+	+	+	-	+	+	+	+	+	+	NA	-	+	11/13
Tamai et al[103]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Thiering et al[104]	+	+	-	+	-	+	+	+	-	+	-	NA	-	+	8/13
Vlajinac et al[105]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Vohr et al[106]	+	+	+	-	-	+	+	-	+	+	-	NA	-	-	7/13
Walker et al[107]	+	+	-	+	-	+	+	+	+	+	+	NA	+	-	10/13
Wang et al[108]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	-	7/11
Watts et al[109]	+	+	-	+	-	-	-	+	+	NA	+	NA	NA	-	6/11
Wells et al[1110]	+	+	+	+	-	-	-	+	+	NA	+	NA	NA	+	8/11
Wells et al[111]	+	+	+	+	-	+	+	+	+	NA	+	NA	-	+	10/12
Wicklow et al[112]	+	+	-	+	+	+	+	+	+	+	+	NA	-	+	11/13
Willig et al[113]	+	+	-	+	-	+	-	+	+	NA	+	NA	NA	+	8/11
Xu et al[114]	+	+	-	+	-	-	-	+	+	NA	-	NA	NA	-	5/11

2.2.3. Data Abstraction

For this review, we extracted data on each study using the Joanna Briggs Institute data extraction form to collect information on: the author(s); study design; study characteristics (for example, type of participants recruited, age range where applicable, study objectives and others); country where the study was conducted; method of BP assessment used; and effect sizes (beta coefficients, odds ratio values, P values, 95% confidence intervals, as appropriate) of the association between the independent variables (risk factors, correlate or determinants) and BP (sBP or dBP) or hypertension (in cases where hypertension was the outcome). Studies were grouped and analysed as identifying possible physiological (factors relating to biology), social (factors relating to conditions in which children live, attend school, grow and develop) and behavioural (factors relating to individual lifestyle or actions) correlates based on the association with BP or hypertension identified in the study. In cases where the study assessed multiple domains, the primary potential correlate was used to assign the study, while other significant correlates were also presented.

2.2.4. Level of Evidence

Studies included in this review were mostly observational, but cut across the full spectrum, including prospective longitudinal cohort, case-control and cross-sectional studies. Given the high threshold for proving causation in epidemiological studies we cannot infer causal links between independent variables and outcome based on study design. However, because of the nature of the design of prospective cohort studies including the temporal association between exposure of interest and outcome measure collected in these studies, prospective cohort studies were generally assigned higher scores (higher scores = less bias) in the risk of bias assessment.

2.2.5. Outcomes

Elevated sBP and/or dBP levels were the most common outcomes identified in the studies included in this review. In certain cases, the values were first transformed to standard deviation (z-scores) in line with common practice in the child population. In addition to sBP and dBP, studies that included varying categories of BP ranges as outcomes such as hypertension ranges using the 95th percentile, or pre-hypertension ranges were also included in this review for analysis.

2.3. Results

2.3.1. Study Characteristics

A total of 9171 papers were retrieved via our electronic search from which 100 studies met the full eligibility criteria and were included for analysis in this systematic review. The flow diagram (Fig. 2.1) details the process of elimination to arrive at the 100 studies. Of those included, 18 (18%) of studies were conducted in the US, 12 in Brazil, seven in China and six each in both Canada and Australia. The other studies were conducted in 32 other countries, while two studies were multi-country. Most studies (67%) used cross-sectional designs, while 4% used case-control approaches and the remaining studies used longitudinal designs. All studies included in this review either adjusted for covariates or utilized multi-level modelling in statistical analysis. However, to allow for an aggregate assessment of studies that addressed similar risk factors, we did not include information on the specific covariates adjusted in the results section as the studies in this review varied significantly in the covariates included (see detailed list of covariates or multi-model approach used in Appendix 1). Generally, most correlates in the social and behavioural domains included were independent of anthropometric factors, while the physiological variables were independent of sociodemographic measures.

2.3.2. Assessment of BP

Fifty-two studies used oscillometric devices for assessing BP, 44 used auscultatory methods, while only four used ambulatory BP monitoring (ABPM) devices, currently considered the gold standard of BP measurement in the paediatric population (115).

2.3.3. Physiological Correlates of BP

Seventy-nine studies included a physiological variable as a possible independent correlate of elevated BP or hypertension. The physiological variables studied included measures of adiposity and height (body mass index [BMI], waist circumference [WC], waist-to-height ratio [WHtR], skin-fold and dual energy X-ray absorptiometry measures); birthweight, post-natal growth and pre-maturity (low birthweight, post-natal growth and pre-term birth); age and puberty (age, peak weight velocity and peak height velocity); sex; familial characteristics (family history of hypertension and genes); peri-gestational characteristics (gestational hypertension, maternal BP, maternal age, maternal weight gain during pregnancy, third trimester BP); and other variables (cardiorespiratory fitness, sleep, cortisol, salivary cotinine and matrix metalloproteinase-2, fasting glucose sodium counter-transport and a genetic risk score) (Fig. 2.2).

Anthropometric Indicators

The most common independent variables were BMI, WHtR and WC (either transformed as standard deviation score [z-scores] or actual values) (n = 55 studies). In all of these, higher adiposity was associated with higher BP or odds of hypertension. This association was observed in cross-sectional studies (n = 46) [16, 17, 21, 23, 26–28, 31, 34, 37–45, 47, 55, 58, 60, 63, 65, 68, 72, 75, 77, 80, 81, 85–90, 93, 94, 98–100, 105, 108, 109, 113, 114], and also in prospective studies (n = 9) [36, 56, 62, 71, 74, 78, 79, 83, 112]. Results were mostly consistent across study type (i.e. cross-sectional or longitudinal), sex and ethnicity.

In certain cases, sex and ethnic differences were observed to modify the magnitude of association between adiposity and BP [56, 105, 113]. For example, while positive associations were observed between BMI and WC with sBP and dBP in Jago *et al*., the effect sizes were markedly higher in boys than in girls [56]. In Vlajinac *et al*., while BMI was associated with sBP and dBP in both sexes, an association with BMI and hypertension was observed only in boys [105]. In one multi-ethnic study consisting of African Americans, European Americans and Hispanic Americans a positive association was reported between adiposity and sBP in the African Americans and European Americans but none in the Hispanic–American group [113].

In addition to BMI, WHtR and WC, other adiposity metrics such as skin-fold measurements and imaging appeared infrequently in the identified studies. These metrics included trunk fat; suprailiac, triceps and biceps skin fold; visceral adipose tissue; total fat mass and total lean mass; total body fat; overall weight; neck circumference (NC); and abdominal circumference (n = 16 studies) [27, 42, 49, 52, 62, 63, 70, 74, 77, 90, 91, 96, 98, 105, 107, 108]. In all these studies, the associations were positive with BP or hypertension, and results were also consistent across study type (i.e. cross-sectional or longitudinal). In one study, interactions were observed between NC and adiposity categories; for example, NC over the 90th percentile and overweight/obesity had higher odds of hypertension compared to those with NC less than the 90th percentile and with normal weight [63].

Similar to adiposity, positive linear associations were observed between height and BP in both sexes cross-sectionally [24, 100, 105] and longitudinally [57, 71] but in boys only in two cross-sectional studies [31, 54]. Consistent with cross-sectional studies, one longitudinal study also reported an association between height and odds of prehypertension and hypertension in both sexes [79]. An exception was reported in one cross-sectional study which observed negative associations with dBP [47].

Birthweight, post-natal growth and pre-maturity

In most studies, birthweight was inversely associated with sBP, dBP or both over a time period [15, 22, 23, 26, 47, 70, 74, 79, 100, 102, 107]. Conversely, two studies reported positive associations between birthweight and BP. Gillman *et al*. reported higher birthweight to be associated with higher BP [46], while Hemachandra *et al*. observed a similarly positive association between birthweight and BP in African–American children but not in White-American children [53].

In Bergel *et al*., the positive association between low birthweight and sBP at ages 5 to 9 years was reported only in children within upper quartiles of BMI at follow-up [20]. This suggests that rapid post-natal growth after birth, not singularly low birthweight, may be responsible for the reported association. This theory was supported by Kagura *et al*. in a South African study which observed that greater relative weight gain in infancy was associated with higher odds of being in an upper BP trajectory [59]. Likewise, Jones *et al*., who used conditional growth to explore the association of weight at different growth periods with BP over time, found that while early post-natal growth might increase BP, its influence was less pronounced [57]. However, the post-natal growth theory was not supported by Walker *et al*. who reported no differences in BP at later ages between children in two distinct weight categories [107].

Pre-term birth was associated with higher BP [24, 106], while an inverse relationship was reported between gestational age and BP [92], suggesting that lower-than-normal gestational time contributes to elevated BP. Infant age when BP was measured (for each additional day of life) was also correlated with higher sBP [46], although it is not exactly clear over what time period in infancy the increase might persist.

Age and Puberty

Age, as a continuous variable, was observed to be significantly associated with sBP and/or dBP in cross-sectional studies [18, 23, 28, 29, 55, 60, 94], with sBP longitudinally (36) and with hypertension in cross-sectional studies [34, 44]. However, the direction of the association was not consistent across all studies, with most studies reporting positive associations, yet with two cross-sectional studies reporting inverse associations [23, 94].

In three cross-sectional studies, age was dichotomized between pre-pubertal/pubertal ages and post-pubertal ages, and their effects were explored with hypertension ranges. For example, when compared against 10-year-olds, 18-year-olds had higher odds of pre-hypertension and hypertension [58]. Similarly, in Xu *et al*., when older children were compared to 8-year-olds, higher risk for hypertension was observed [114]. The risk was most pronounced in 17-year-old boys, who had a 13-fold risk of hypertension, while the girls had an eightfold risk [114]. When compared with 15-year-old boys, 18-year-old boys had higher odds of pre-hypertension [87].

Sexual maturity was positively associated with BP in both boys and girls in one cross-sectional study [31]. Likewise, a two-standard-deviation increase in peak weight velocity and peak height velocity in infancy, both measures of maturity, were positively associated with higher BP at the age of 10 years [104].

Sex

In most studies reviewed, sex was either explored as a covariate, or used in stratification for statistical analysis. Only five papers explored the independent effect of sex on BP or hypertension. Sex associations with BP were mostly consistent across the studies, with male sex mostly associated with higher BP in cross-sectional [55, 68] and longitudinal studies [83, 106], except in Kaczmarek *et al*., in which females were more likely to develop pre-hypertension, but less likely to develop hypertension [58].

Familial characteristics

Familial characteristics such as parental or family history of hypertension resulted in higher BP in children in six cross-sectional studies [26, 47, 51, 58, 60, 100], and one longitudinal study [78]. Likewise, a genetic risk score (calculated from a discovery sample using single nucleotide polymorphisms) prospectively explained only 1.4% of the variance in dBP, and 0.8% of the variance in sBP [101].

Peri-gestational Characteristics

Peri-gestational characteristics such as gestational hypertension [100], maternal BP [15, 69], increase in maternal BP after birth, maternal weight gain during pregnancy [61], maternal age and third trimester maternal BP (46) were associated with higher child BP over time. Wells *et al*. also reported that first born children had higher BP in adolescence when compared to non-first born children (111).

Other Physiological Variables

Additional variables appeared infrequently in cross-sectional studies as significant risk factors for BP or hypertension. Cardiorespiratory fitness was inversely associated with sBP in girls in one cross-sectional study [80], while Bergmann *et al*., also using cross-sectional data reported that less fit individuals had higher odds of developing pre-hypertension compared to more fit individuals [21]. Interaction effects were also observed between overweight and being unfit such that those who were both overweight and unfit had the highest odds of becoming pre-hypertensive [21]. Total cortisol [67], a hormone activated in response to stress, and matrix metalloproteinase2 [95], an enzyme involved in the breakdown of the extracellular matrix, and also known to modulate vascular inflammation, were both positively associated with sBP in cross-sectional studies. Similarly, increased resting heart rate was associated with higher odds of hypertension longitudinally [36], and cross-sectionally [30].

Mu *et al*. reported prospective associations between higher baseline sodium counter transport and the risk of hypertension [78]. One longitudinal study reported fasting glucose to be positively associated with both sBP and dBP [48], while one cross-sectional study reported the linear association between BMI and WHtR with BP to be mediated by insulin resistance [35]. Furthermore, salivary cotinine, a marker of exposure to tobacco, was positively associated with BP cross-sectionally [55]. Similarly, in cross-sectional studies, daytime sleepiness was associated with a positive indirect effect on hypertension risk [88] and sleep duration was inversely associated with sBP [110], while those who ranked in the upper tertile of reporting a sleep disturbance score had higher risk of hypertension compared to those in the lower tertile [82].

2.3.4. Social Correlates of BP

Relative to the number of identified studies that primarily explored physiological correlates, those exploring social factors in relation to BP in children and adolescents were comparably fewer in number, and included a diverse range of variables – mostly proxies for social status and stress.

Socioeconomic Variables and Ethnicity

In cross-sectional studies, a range of socioeconomic variables and ethnicities were associated with BP or hypertension. McGrath *et al*. reported lower neighbourhood income (those at or below poverty levels) and neighbourhood socioeconomic status (percentage at or below poverty levels) to be positively associated with sBP [73]. Children with unemployed fathers or those who lived in households with inadequate incomes were more likely to be prehypertensive compared with those who had employed fathers or lived in households with adequate incomes [58]. Additionally, perceived everyday discrimination [50] and chronic negative life events (for example, family argument with relatives, family members involved with drug or alcohol, family having problems with finances) [25] were positively associated with BP. Clark *et al*. also reported inverse associations between violence exposure and task-induced BP changes [33].

One Chinese study exploring differences in risk for different ethnicities observed that compared to Han ethnic group, children of the Yi or Mongolia ethnicity had higher odds of developing hypertension [114]. In the Heartfelt study, ethnicity was also independently associated with BP such that Mexican Americans and African Americans had lower BP compared to White Americans [31]. White-American individuals also had lower dBP when compared to African–American individuals [73]. Moreover, interactions were observed between White-American ethnicity (compared to African–Americans) and negative mood, with individual household income and negative mood, resulting in inverse associations with sBP and dBP [73].

Parental Education

Kwok *et al*. reported associations between low parental education and childhood BP prospectively. The association was observed to be mediated by BMI at adolescence (proportion mediated: 24%) and maternal BMI (18% mediated) [64]. Similarly, inverse associations were observed between maternal education and sBP in another longitudinal study [53], while low parental education was associated with BP in a cross-sectional study [51].

Other Variables

In Congolese school children, being in secondary school and migration from rural areas to the capital city (Brazzaville) were associated with higher odds of pre-hypertension cross-sectionally [72]. Conversely, in another cross-sectional study, Polish adolescents who resided in large cities were less likely to develop systolic pre-hypertension and systolic hypertension compared to those from rural areas [58]. Additionally, Chinese individuals living in suburban neighbourhoods compared to those in urban neighbourhoods had higher risk for hypertension [114]. As well, maternal perception of their child's body shape was independently associated with BP in a cross-sectional study, for Italian male and female children, with those having above median maternal perception (considered to be fatter body types) also having higher BP [19].

2.3.5. Behavioural Correlates of BP

Sedentary behaviour such as watching TV, using computers, playing video games and watching TV while eating, coupled with inadequate physical activity, was reported in both cross-sectional (n = 4) [32, 45, 66, 110] and longitudinal studies (n = 1) [83] to increase BP or the odds of hypertension in children.

Meanwhile, two other cross-sectional studies observed higher physical activity levels to be associated with lower dBP [29, 60]. In one longitudinal study, as well, physical activity of <60 minutes a day compared to reference values of ≥ 60 minutes a day was associated with higher risk of hypertension [76], while a decline of one moderate-to-vigorous physical activity session per week with each year of age was associated with higher BP [71].

Smoking and Alcohol Use

In older children, the number of cigarettes smoked weekly was prospectively associated with higher sBP [71]. The links between parental smoking were also explored in cross-sectional studies, with parental smoking associated with higher BP [51, 100]. Similarly, alcohol consumption in older children was observed to increase the likelihood of pre-hypertension [87].

Diet

Unhealthy food choice survey scores [29] and high consumption of processed red meat and cheese [43] were associated with higher SBP and odds of hypertension respectively in cross-sectional studies. Likewise, dietary fat consumption of 10 g per day was longitudinally associated with sBP [97]. Total fat, saturated fat and monounsaturated fat intake were also associated with sBP [16]. One cross-sectional study reported high intakes of vitamin B12 and folic acid to be associated with reduced BP in children [103]. Maternal dietary characteristics such as pre-natal fat intake and pre-natal carbohydrate intake (between 270 and 447 g) were both associated with higher BP in one longitudinal study [84]. Complementary feeding (time of introduction of solid food) lower than 5 months or higher than 6 months [26] and being malnourished [96] were also both associated with higher BP.

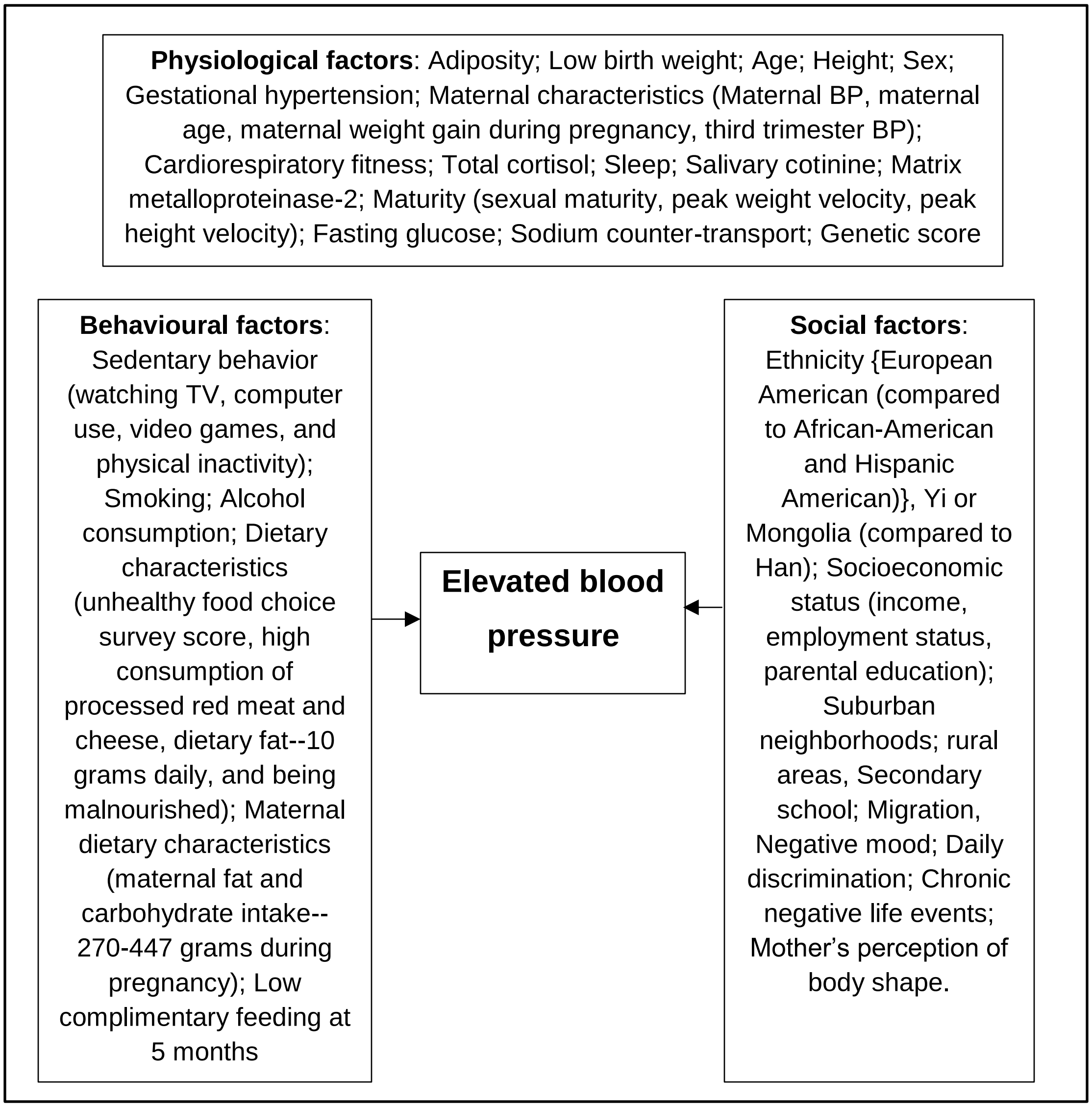


Figure 2.2 Multi-level correlates of elevated BP reported in this systematic review

2.4. Discussion

In this systematic review, we evaluated and summarized the evidence for potential correlates of BP and hypertension in children aged 18 years and younger. The variables identified in the reviewed studies varied significantly, with several studies identifying more than one correlate. However, the correlates all fell within one of three domains: physiological, social and behavioural (see Fig. 2.2 for high-level framework). Moreover, because of broad variation in BP and in statistical methodology identified in the studies, a narrative synthesis of the evidence was undertaken, as opposed to a meta-analysis.

The measurements of BP used mainly were auscultatory and oscillometric devices, with only four studies using ABPM. The advantage of oscillometric devices lies in their ease of use and convenience, especially in epidemiological studies where individuals with limited clinical expertise may be required to collect BP measurements. However, studies that have compared oscillometric devices against mercury sphygmomanometers report that oscillometric methods have yielded significantly higher sBP values [116]. Thus, obtaining BP by oscillometry could result in an overestimation of BP values, and consequently, an over-reporting of the actual high BP prevalence in the paediatric population. Similarly, it should be noted that BP obtained using a cuff and sphygmomanometer is indicative of peripheral (brachial artery values) BP and not central (aortic values) BP. Current evidence suggests that central BP, which is usually lower than peripheral BP, might be more related to future CVD events than peripheral BP. This fact has important implications for the epidemiology of BP and provides noteworthy suggestions for the measurement of BP going forward [117]. In studies where hypertension was the outcome, the definition of BP as systolic/diastolic at the 95th percentile for age, sex and height was mostly adopted [3]. Noteworthy differences were observed based on the number of repeated BP measurements used in the studies to diagnose hypertension. The current recommendation by the National High Blood Pressure Education Program (NHBPEP) specifies that BP be measured on three separate occasions to make a diagnosis of hypertension [3]. Discrepancies were observed in some of the studies reviewed in this analysis on this basis, including not adhering to the recommendation to measure BP three times for the diagnosis of hypertension [28, 34, 38, 66, 75, 83, 86, 88, 91, 106, 114]. It is unclear what impact this might have had on the studies; however, to avoid methodological discrepancies, consistency in the way hypertension in children is measured and diagnosed is needed in future studies.

For most of the studies included in this review, the anthropometric variables and BP variables were first transformed to z-scores as is common practice in the paediatric population. This is important because in growing children these indicators are impacted by height, age and sex, so as such, standardizing these measures allows for unique comparisons across children with similar ages and sex. Calculating z-scores requires the use of reference population data on growth charts, most of which have been based on US data. This poses certain limitations especially in developing countries where growth patterns may not exactly mirror US standards. The WHO 2007 reference data address this limitation by utilizing a reference sample from six countries including developing countries [118]. However, it is still unclear how representative the six countries included are of the international population. Important considerations need to be addressed by researchers undertaking research that utilize these variables, ensuring that the reference z-score used mirrors the specific target population to avoid the propagation of spurious results.

Unsurprisingly, consistent associations were observed between adiposity and BP in this review, with a majority of the studies utilizing field methods to determine adiposity. In addition, we observed evidence of a dose-response relationship in certain studies in that increasing adiposity was associated with greater risk magnitude [21, 38, 43, 114]. Taken together, the consistency in association and the dose– response evidence may provide support for a possible causal relationship between adiposity and elevated BP in children. Moreover, in this review some studies further examined the effect of sex and ethnicity on the relationship between adiposity and BP in stratified analyses. Differences in the magnitude of effect size were mostly observed by sex, while one study reported differences by ethnicity. Willig *et al*. reported associations between adiposity and elevated sBP in European-Americans and African-Americans but not in Hispanic-Americans; the Hispanic-Americans in that study were reported to have the lowest BP and hypertension rates [113]. Given that trends in adiposity for Hispanic-American children were observed to be higher than African Americans and European Americans, it is unclear what accounts for this seemingly paradoxical effect observed in Hispanic-Americans. The authors attribute this outcome partly to the presence of the ‘healthy immigrant effect’ owing to less acculturation, as the Hispanic-Americans in this study were mostly first-generation immigrants [113]. Likewise, the differences observed by sex for boys and girls could be attributed to pubertal differences between boys and girls that results in disparities in sex hormonal levels that might accompany the pubertal phase in children [18]. It is also possible that differences in obesity phenotypes, where distinctions in fat mass are observed by gender and ethnicity for individuals at similar BMI levels, might explain these risk differentials.

The contributory role of familial links in the pathophysiology of elevated BP and hypertension was sporadically highlighted across the range of studies examined. Variables such as parental hypertension [60] and family history of hypertension [47, 58, 78] were reported to be positively associated with elevated BP, and in some cases hypertension. Only one study explicitly explored the direct role of genes (by using a genetic risk score calculated using single nucleotide polymorphisms from a discovery sample) in predicting children's BP, accounting for about 1% of the observed BP variance [101]. The authors also noted that a large number of genetic variants responsible for a significant variance in BP remain unidentified. It is widely known that parental or familial history of hypertension increases risk in children. However, the specific genes responsible are as yet unknown. Taal *et al*. showed data that suggest that it is the combined effect of multiple genes rather than single genes that may be critical [101]. Some studies have shown that genes involved in the regulation of BP via sodium reabsorption may be implicated [119]. Similarly, an understanding of genes which play a part in other pathways through which BP is regulated – such as the renin-angiotensin aldosterone system, baroreceptor control, endothelial ion channels and the sympathetic nervous system – have been suggested to hold potential in improving the understanding of the specific roles of other genes linked to elevated BP [120]. However, it is important to note that only a small proportion of hypertension in children is genetically determined, thus underscoring the great potential for significant impact through the identification of modifiable social and behavioural risk factors.

Supporting the foetal origins hypothesis – which proposes that developmental conditions *in utero* could affect risk for CVDs [121] – is the fact that birthweight was consistently inversely associated with BP over time in the studies included in the review. There were exceptions in only two studies, which both reported linear positive associations as opposed to inverse relationship with BP levels [46, 53]. Results from other studies identified in this review suggest that the relationship between birthweight and BP may be mediated in part through accelerated post-natal growth [20, 59]. These findings were also supported by Huxley *et al*. who reported that three studies identified in their systematic review observed a positive association between catch-up growth and BP [13]. However, these authors also reported that it was unclear whether the associations observed in those studies were independent of pre-natal growth given that the assessment of post-natal growth included birthweight. Given the statistical approach adopted by the studies, it is unclear whether the association between accelerated post-natal growth and BP occurs completely independently of pre-natal growth. More studies are therefore needed. Perhaps striking is the fact that dietary habits during pregnancy such as fat and carbohydrate intake above certain thresholds were also shown to predict children's BP levels. While this finding might provide backing for the foetal origin hypothesis, it also highlights the intricate connection between maternal and foetal/child physiology, suggesting that damage to endothelial and vascular function which might occur as a result of poor diet [122] may have consequences during gestation which might track through childhood [123, 124]. The relationship between parental smoking and children's BP observed in this review is also reflective of the deleterious effect of exposure to second-hand smoke on BP directly via damage to endothelial or vascular function.

The association between the range of behavioural and social factors identified in this review underscores the multifactorial aetiology of BP and hypertension, and their potential modifiability. Most of the behavioural variables identified confirm already-known theories in the adult population – that sedentariness, poor diet and unhealthy behaviours such as smoking and excessive alcohol consumption have profound implications for chronic heart disease risk. The social correlates identified in this review re-affirm the presence of a social gradient in health, in this case risk for higher BP or hypertension. The intersection between ethnicity and socioeconomic status was also highlighted in one study which reported neighbourhood socioeconomic status to be predictive of BP [73]. Potential pathways by which this might occur are reflective of systemic racial inequities where black-populated neighbourhoods in the US experience overcrowding, crime, unemployment and violence [50, 73] – all of which increase stress and concomitant disturbances in the neuro-endocrine system, which when prolonged could significantly increase chronic disease risk. It is important to note that the relationship between stress and BP also occurs independently of ethnicity or location as revealed in Brady and Matthews [25]. However, in countries such as the US, exposure to stressors may disproportionately vary by ethnicity [125]. It is also unclear whether the pathway linking the Yi and Mongolia ethnicities in China to a higher risk of hypertension are consistent with patterns observed in the US, as the authors attribute the ethnic differences observed in their study to differences in diet and lifestyle by ethnicity in China [114].

It should be noted that while the studies included in this review either adjusted for covariates or utilized multi-variable approaches, the studies varied considerably in the covariates included. For example, some of the physiological correlates included only scant sociodemographic measures such as age and sex while others studies were more robust in their inclusion of covariates. The risk of bias assessment provides information on studies that we felt were not satisfactory in the multi-variable approach adopted or number of covariates included. The results of the studies included in this review should be viewed with these limitations in mind.

Last, in aggregate, the research evidence examined in this review shows that while some risk factors for hypertension have been extensively studied in children, the impact of other risk factors extensively detailed in adults, such as sodium intake, may be understudied in children. By systematically reviewing the evidence on correlates and risk factors for hypertension, we provide insight into areas that have been explored and those that remain under-explored and may require further evidence in the child population. This review nevertheless provides vital information for public health practitioners and policy-makers regarding factors that could be addressed to begin to lower the burden associated with elevated BP and hypertension in children.

2.4.1. Recommendations

Based on the studies examined in this review, six recommendations are highlighted for consideration for research, policy and practice. First, inconsistencies observed in some studies regarding how BP was assessed should be addressed by ensuring adherence to recommendations specified by the NHBPEP to facilitate comparing and pooling of data from different studies. Second, given the multi-factorial correlates identified for BP and their inter-relatedness, future studies should employ robust multi-level modelling to explore risk determination and prioritize targets of intervention. Third, multi-ethnic studies that allow for the investigation of variations in susceptibilities will improve our understanding of potential ethnic pre-disposition to risk in children. Fourth, public health interventions aimed at addressing some of the behavioural correlates outlined here, including those that emphasize physical activity and prioritize healthy eating in addition to screening and treatment using evidence-based 'best bets' for known physiological risk factors such as obesity [126] are especially necessary. Similarly, interventions such as health education for mothers, particularly during prenatally, or even before conception could help address some of the peri-gestational risk factors documented here. Fifth, to address the deleterious impact of socioeconomic disadvantage on health outcomes, policies – such as redistributive taxes and cash transfer programs – aimed at creating conditions that promote social and health equity across populations and that take a life-course approach are essential. Last, as clinicians play a frontline role in the treatment of hypertension in children, the evidence from this study provides an update on risk factors that need to be considered by clinicians in their assessments to address the deleterious impact of elevated BP and hypertension in children.

2.4.2. Strengths and Limitations

The strength of this review lies in its comprehensive scope that allowed for the detailed examination of multi-factorial correlates of BP. The use of multiple search databases meant that we were also able to capture a diverse range of studies. The identification of important modifiable risk factors for elevated BP provides information for health practitioners and policy makers. Conversely, this review has limitations. The criteria for inclusion – such as studies being conducted in general population samples, studies that specified how BP was measured, and studies conducted/reported in English – may have meant that relevant studies were missed. However, implementing such rigorous inclusion criteria was meant to facilitate a detailed appraisal of the studies included. As the studies in this review were all observational studies, we are unable to attribute causal relationships between risk factor and outcome. Finally, due to the broad range of correlates, we were unable to perform meta-analysis of the results and so were limited to using a narrative analysis only.

2.5. Conclusion

We identified a broad range of physiological, social and behavioural correlates of BP and hypertension in children and adolescents, providing evidence to support the multifactorial aetiology of BP. Despite issues discussed in this review such as the differences in covariates included or how BP was measured, our findings nevertheless provide insight regarding risk factors or correlates that could begin to be addressed in tackling the upsurge in the prevalence of hypertension in children. Interventions aimed at improving social conditions for children and addressing the wider social determinants allows for the remediation of social inequities that may contribute to elevated BP and hypertension in children. Last, studies that emphasize robust methodologies such as longitudinal designs and multi-ethnic recruitment in populations that are known to be disproportionately burdened by chronic disease risk will improve understanding of the aetiology of hypertension and provide concrete information on the temporality and dose–response in risk associations.

Given the increasing burden of hypertension in children and its associated sequelae throughout adulthood for individuals and for populations, the evidence outlined in this review supports the need for a concerted and multifactorial approach to preventing hypertension starting in childhood.

2.6. References

1. Murray CJL, Vos T, Lozano R et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the global burden of disease study 2010. *Lancet* 2012; 380: 2197–2223. https://doi.org/10. 1016/S0140-6736(12)61689-4.

2. World Health Organization. A Global Brief on Hypertension, 2013. URL http://apps.who.int/iris/bitstream/10665/79059/1/ WHO_DCO_WHD_2013.2_eng.pdf?ua=1 (accessed January 2018).

3. National High Blood Pressure Education Program Working Group on High Blood. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* 2004; 114: 555–576. https://doi.org/10.1542/ peds.114.2.S2.555.

4. Feber J, Ahmed M. Hypertension in children: new trends and challenges. *Clin Sci* 2010; 119: 151–161. https://doi.org/10.1042/ CS20090544.

5. Din-Dzietham R, Liu Y, Bielo MV, Shamsa F. High blood pres- sure trends in children and adolescents in national surveys, 1963 to 2002. *Circulation* 2007; 116: 1488–1496. https://doi.org/10. 1161/CIRCULATIONAHA.106.683243.

6. Xi B, Liang Y, Mi J. Hypertension trends in Chinese children in the national surveys, 1993 to 2009. *Int J Cardiol* 2013; 165: 577–579. https://doi.org/10.1016/j.ijcard.2012.09.032.

7. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: the NHANES experience 1988-2008. *Hypertension* 2013; 62: 247–254. https://doi.org/10.1161/HYPERTENSIONAHA.111.00831.

8. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation* 2008; 117: 3171–3180. https://doi.org/10.1161/ CIRCULATIONAHA.107.730366.

9. Thompson DR, Obarzanek E, Franko DL et al. Childhood overweight and cardiovascular disease risk factors: the National Heart, Lung, and Blood Institute growth and health study. *J Pediatr* 2007; 150: 18–25. https://doi.org/10.1016/j.jpeds.2006. 09.039.

10. Nadeau KJ, Maahs DM, Daniels SR, Eckel RH. Childhood obesity and cardiovascular disease: links and prevention strategies. *Nat Rev Cardiol* 2011; 8: 513–525. https://doi.org/10.1038/ nrcardio.2011.86.

11. Falkner B. Hypertension in children and adolescents: epidemiology and natural history. *Pediatr Nephrol* 2010; 25: 1219–1224. https://doi.org/10.1007/s00467-009-1200-3.

12. Coelli AP, Nascimento LR, Mill JG, Molina Mdel CB. Preterm birth as a risk factor for high blood pressure in children: a systematic review. *Cad Saude Publica* 2011; 27: 207–218.

13. Huxley RR, Shiell AW, Law CM. The role of size at birth and postnatal catch-up growth in determining systolic blood pressure. *J Hypertens* 2000; 18: 815–831. https://doi.org/10. 1097/00004872-200018070-00002.

14. National Institutes of Health: National Heart Lung and Blood Institute. Study Quality Assessment Tools: Quality Assessment Tool for Observational Cohort and Cross Sectional Studies. URL https://www.nhlbi.nih.gov/health-topics/study-quality-assessment- tools (accessed January 2018).

15. Adair LS, Kuzawa CW, Borja J. Maternal energy stores and diet composition during pregnancy program adolescent blood pressure. *Circulation* 2001; 104: 1034–1039.

16. Aeberli I, Spinas GA, Lehmann R et al. Diet determines features of the metabolic syndrome in 6- to 14-year-old children. *Int J Vitam Nutr Res* 2009; 79: 14–23. https://doi.org/10. 1024/0300-9831.79.1.14.

17. Akis¸ N, Pala K, Meriç-Utku A et al. Hypertension in children (12-14 years) – a case-control study in Bursa, Turkey. *Turk J Pediatr* 2009; 51: 437–443.

18. Barba G, Casullo C, Dello Russo M et al. Gender-related differences in the relationships between blood pressure, age, and body size in prepubertal children. *Am J Hypertens* 2008; 21: 1007–1010. https://doi.org/10.1038/ajh.2008.228.

19. Barba G, Casullo C, Russo P, Siani A, for the ARCA Project Study Group. Gender inequalities in maternal perception of healthy child body shape and their association with child body mass and blood pressure. *Int J Pediatr Obes* 2008; 3: 78–83. https://doi.org/10.1080/17477160701667420.

20. Bergel E, Haelterman E, Belizan J, Villar J, Carroli G. Perina- tal factors associated with blood pressure during childhood. *Am J Epidemiol* 2000; 151: 594–601. https://doi.org/10.1093/ oxfordjournals.aje.a010247.

21. Bergmann GG, de Araújo Bergmann ML, Hallal PC. Independent and combined associations of cardiorespiratory fitness and fatness with cardiovascular risk factors in Brazilian youth. *J Phys Act Health* 2014; 11: 375–383. https://doi.org/10.1123/jpah. 2011-0342.

22. Blake KV, Gurrin LC, Evans SF et al. Adjustment for current weight and the relationship between birth weight and blood pres- sure in childhood. *J Hypertens* 2000; 18: 1007–1012.

23. Bohlke M, Dullius F, Menezes J et al. Predictors of higher blood pressure in a clinical setting in normotensive children: a prospective study. *Kidney Blood Press Res* 2009; 32: 205–209. https://doi.org/10.1159/000226427.

24. Bonamy A-KE, Martin H, Jörneskog G, Norman M. Lower skin capillary density, normal endothelial function and higher blood pressure in children born preterm. *J Intern Med* 2007; 262: 635–642. https://doi.org/10.1111/j.1365-2796.2007.01868.x.

25. Brady SS, Matthews KA. Chronic stress influences ambulatory blood pressure in adolescents. *Ann Behav Med* 2006; 31: 80–88.

https://doi.org/10.1207/s15324796abm3101_12.

26. Brambilla P, Bedogni G, Pietrobelli A, Cianfarani S, Agostoni C. Predictors of blood pressure at 7-13 years: the “new millennium baby” study. *Nutr Metab Cardiovasc Dis* 2016; 26: 706–712. https://doi.org/10.1016/j.numecd.2015.11.005.

27. Brion MA, Ness AR, Davey Smith G, Leary SD. Association between body composition and blood pressure in a contemporary cohort of 9-year-old children. *J Hum Hypertens* 2007; 21: 283–290. https://doi.org/10.1038/sj.jhh.1002152.

28. Burgos MS, Burgos LT, Camargo MD et al. Relationship between anthropometric measures and cardiovascular risk factors in children and adolescents. *Arq Bras Cardiol* 2013; 101: 288–296. https://doi.org/10.5935/abc.20130169.

29. Chen J-L, Weiss S, Heyman MB, Lustig R. Risk factors for obesity and high blood pressure in Chinese American children: maternal acculturation and children’s food choices. *J Immigr Minor Health* 2011; 13: 268–275. https://doi.org/10.1007/s10903-009-9288-x.

30. Chirico D, Wade TJ, Cairney J, Klentrou P, O’Leary DD. Evi- dence of a hyperkinetic state in children with elevated blood pres- sure. *Ann Hum Biol* 2015; 42: 248–254. https://doi.org/10. 3109/03014460.2014.940064.

31. Cho SD, Mueller WH, Meininger JC, Liehr P, Chan W. Blood pressure and sexual maturity in adolescents: the heartfelt study. *Am J Hum Biol*. 2001; 13: 227–234. https://doi.org/10.1002/1520-6300(200102/03)13:2<227::AID-AJHB1033>3.0.CO;2-K.

32. Christofaro DGD, De Andrade SM, Cardoso JR et al. High blood pressure and sedentary behavior in adolescents are associated even after controlling for confounding factors. *Blood Press* 2015; 24: 317–323. https://doi.org/10.3109/08037051.2015. 1070475.

33. Clark R, Benkert RA, Flack JM. Violence exposure and optimism predict task-induced changes in blood pressure and pulse rate in a normotensive sample of inner-city black youth. *Psychosom Med* 2006; 68: 73–79. https://doi.org/10.1097/01.psy. 0000195744.13608.11.

34. Colín-Ramírez E, Castillo-Martínez L, Orea-Tejeda A et al. Waist circumference and fat intake are associated with high blood pressure in Mexican children aged 8 to 10 years. J Am Diet Assoc 2009; 109: 996–1003. https://doi.org/10.1016/j.jada. 2009.03.011.

35. Correia-Costa L, Santos AC, Severo M et al. Sex-specific medi- ating role of insulin resistance and inflammation in the effect of adiposity on blood pressure of prepubertal children*. PLoS One* 2015; 10: e0132097. https://doi.org/10.1371/journal.pone. 0132097.

36. Dasgupta K, O’Loughlin J, Chen S et al. Emergence of sex differences in prevalence of high systolic blood pressure: analysis of a longitudinal adolescent cohort. *Circulation* 2006; 114: 2663–2670. https://doi.org/10.1161/CIRCULATIONAHA.106. 624536.

37. de Onis M, Martínez-Costa C, Núñez F et al. Association between WHO cut-offs for childhood overweight and obesity and cardiometabolic risk. Public Health Nutr 2013; 16: 625–630. https://doi.org/10.1017/S1368980012004776.

38. Dinç G, Saatli G, Baydur H, Ozcan C. Hypertension and over- weight among Turkish adolescents in a city in Aegean region of Turkey: a strong relationship in a population with a relatively low prevalence of overweight. *Anadolu Kardiyol Derg* 2009; 9: 450–456.

39. Dong B, Wang Z, Yang Y, Wang H-J, Ma J. Intensified associ- ation between waist circumference and hypertension in abdomi- nally overweight children. *Obes Res Clin Pract* 2016; 10: 24–32. https://doi.org/10.1016/j.orcp.2015.04.002.

40. Dong J, Guo X-L, Lu Z-L et al. Prevalence of overweight and obesity and their associations with blood pressure among children and adolescents in Shandong, China. *BMC Public Health* 2014; 14: 1080. https://doi.org/10.1186/1471-2458-14-1080.

41. Dulskiene V, Kuciene R, Medzioniene J, Benetis R. Associa- tion between obesity and high blood pressure among Lithuanian adolescents: a cross-sectional study. *Ital J Pediatr* 2014; 40: 102. https://doi.org/10.1186/s13052-014-0102-6.

42. Eisenmann JC, Wrede J, Heelan KA. Associations between adiposity, family history of CHD and blood pressure in 3–8 year- old children. *J Hum Hypertens* 2005; 19: 675–681. https://doi. org/10.1038/sj.jhh.1001882.

43. Farajian P, Panagiotakos DB, Risvas G et al. Dietary and life- style patterns in relation to high blood pressure in children: the GRECO study. *J Hypertens* 2015; 33: 1174–1181. https://doi. org/10.1097/HJH.0000000000000536.

44. Flores-Huerta S, Klünder-Klünder M, Reyes de la Cruz L, Santos JI. Increase in body mass index and waist circumference is associated with high blood pressure in children and adolescents in Mexico City. *Arch Med Res* 2009; 40: 208–215. https://doi. org/10.1016/j.arcmed.2009.02.009.

45. Gaya AR, Alves A, Aires L et al. Association between time spent in sedentary, moderate to vigorous physical activity, body mass index, cardiorespiratory fitness and blood pressure. *Ann Hum Biol* 2009; 36: 379–387. https://doi.org/10. 1080/03014460902817976.

46. Gillman MW, Rich-Edwards JW, Rifas-Shiman SL et al. Maternal age and other predictors of newborn blood pressure. *J Pediatr* 2004; 144: 240–245. https://doi.org/10.1016/j.jpeds. 2003.10.064.

47. Goel M, Pal P, Agrawal A, Ashok C. Relationship of body mass index and other life style factors with hypertension in adoles- cents. *Ann Pediatr Cardiol* 2016; 9: 29. https://doi.org/10. 4103/0974-2069.171393.

48. Goharian TS, Andersen LB, Franks PW et al. Examining the causal association of fasting glucose with blood pressure in healthy children and adolescents: a Mendelian randomization study employing common genetic variants of fasting glucose. *J Hum Hypertension* 2015; 29: 179–184. https://doi.org/10.1038/jhh.2014.63.

49. Going SB, Lohman TG, Cussler EC et al. Percent body fat and chronic disease risk factors in U.S. children and youth. *Am J Prev Med* 2011; 41: S77–S86. https://doi.org/10.1016/j.amepre.2011. 07.006.

50. Goosby BJ, Malone S, Richardson EA, Cheadle JE, Williams DT. Perceived discrimination and markers of cardiovascular risk among low-income African American youth. *Am J Hum Biol* 2015; 27: 546–552. https://doi.org/10.1002/ajhb.22683.

51. Hacke C, Weisser B. Effects of parental smoking on exercise systolic blood pressure in adolescents. *J Am Heart Assoc* 2015; 4: e001936. https://doi.org/10.1161/JAHA.115.001936.

52. He Q, Horlick M, Fedun B et al. Trunk fat and blood pressure in children through puberty. *Circulation* 2002; 105: 1093–1098.

53. Hemachandra AH, Klebanoff MA, Furth SL. Racial disparities in the association between birth weight in the term infant and blood pressure at age 7 years: results from the collaborative perinatal project. *J Am Soc Nephrol* 2006; 17: 2576–2581. https:// doi.org/10.1681/ASN.2005090898.

54. Huang R-C, de Klerk N, Mori TA et al. Differential relation- ships between anthropometry measures and cardiovascular risk factors in boys and girls. Int J *Pediatr Obes* 2011; 6: e271–e282. https://doi.org/10.3109/17477166.2010.512388.

55. Huntington-Moskos L, Turner-Henson A, Rice M. Tobacco exposure, weight status, and elevated blood pressure in adolescents. *J Community Health* 2014; 39: 653–659. https://doi.org/10. 1007/s10900-014-9839-5.

56. Jago R, Mendoza JA, Chen T, Baranowski T. Longitudinal associations between BMI, waist circumference, and cardiometabolic risk in US youth: monitoring implications. *Obesity* 2013; 21: E271–E279. https://doi.org/10.1002/oby.20080.

57. Jones A, Charakida M, Falaschetti E et al. Adipose and height growth through childhood and blood pressure status in a large prospective cohort study. *Hypertension* 2012; 59: 919–925. https://doi.org/10.1161/HYPERTENSIONAHA.111.187716.

58. Kaczmarek M, Stawinska-Witoszynska B, Krzyżaniak A, Krzywinska-Wiewiorowska M, Siwinska A. Who is at higher risk of hypertension? Socioeconomic status differences in blood pressure among Polish adolescents: a population-based ADOPOLNOR study. *Eur J Pediatr* 2015; 174: 1461–1473. https://doi.org/10. 1007/s00431-015-2554-0.

59. Kagura J, Adair LS, Munthali RJ, Pettifor JM, Norris SA. Association between early life growth and blood pressure trajectories in black South African children. *Hypertension* 2016; 68: 1123–1131. https://doi.org/10.1161/HYPERTENSIONAHA.116. 08046.

60. Katona E, Zrínyi M, Komonyi E et al. Factors influencing adolescent blood pressure: the Debrecen hypertension study. *Kidney Blood Press Res* 2011; 34: 188–195. https://doi.org/10. 1159/000326115.

61. Khoury J, Knutsen M, Stray-Pedersen B, Thaulow E, Tonstad S. A lower reduction in umbilical artery pulsatility in mid- pregnancy predicts higher infant blood pressure six months after birth. *Acta Paediatr* 2015; 104: 796–800. https://doi.org/10.1111/ apa.13020.

62. Klakk H, Grøntved A, Møller NC et al. Prospective associa- tion of adiposity and cardiorespiratory fitness with cardiovascular risk factors in healthy children. *Scand J Med Sci Sports* 2014; 24: e275–e282. https://doi.org/10.1111/sms.12163.

63. Kuciene R, Dulskiene V, Medzioniene J. Association of neck circumference and high blood pressure in children and adolescents: a case-control study. *BMC Pediatr* 2015; 15: 127. https://doi. org/10.1186/s12887-015-0444-2.

64. Kwok MK, Schooling CM, Subramanian SV, Leung GM, Kawachi I. Pathways from parental educational attainment to ado- lescent blood pressure. *J Hypertension* 2016; 34: 1787–1795. https://doi.org/10.1097/HJH.0000000000001003.

65. Landazuri P, Granobles C, Loango N. Gender differences in serum angiotensin-converting enzyme activity and blood pressure in children: an observational study. *Arq Bras Cardiol* 2008; 91: 352–357.

66. Lazarou C, Panagiotakos DB, Matalas A-L. Lifestyle factors are determinants of children's blood pressure levels: the CYKIDS study. *J Hum Hypertens* 2009; 23: 456–463. https://doi.org/10. 1038/jhh.2008.151.

67. Le-Ha C, Herbison CE, Beilin LJ et al. Hypothalamic-pituitary-adrenal axis activity under resting conditions and cardiovas- cular risk factors in adolescents. *Psychoneuroendocrinology* 2016; 66: 118–124. https://doi.org/10.1016/j.psyneuen.2016.01.002.

68. Leung LCK, Sung RYT, So H-K et al. Prevalence and risk factors for hypertension in Hong Kong Chinese adolescents: waist circumference predicts hypertension, exercise decreases risk. *Arch Dis Child* 2011; 96: 804–809. https://doi.org/10.1136/adc.2010.202770.

69. Lim W-Y, Lee Y-S, Yap FK-P et al. Maternal blood pressure during pregnancy and early childhood blood pressures in the off- spring: the GUSTO birth cohort study. *Medicine* 2015; 94: e1981. https://doi.org/10.1097/MD.0000000000001981.

70. Lurbe E, Torro I, Rodríguez C, Alvarez V, Redón J. Birth weight influences blood pressure values and variability in children and adolescents. *Hypertension* 2001; 38: 389–393.

71. Maximova K, O'Loughlin J, Paradis G, Hanley JA, Lynch J. Declines in physical activity and higher systolic blood pressure in adolescence. *Am J Epidemiol* 2009; 170: 1084–1094. https://doi. org/10.1093/aje/kwp255.

72. Ellenga Mbolla BF, Okoko AR, Mabiala Babela JR et al. Pre- hypertension and hypertension among schoolchildren in Brazzaville, Congo. *Int J Hypertens* 2014; 2014: 1–6. https://doi.org/10. 1155/2014/803690.

73. McGrath JJ, Matthews KA, Brady SS. Individual versus neighborhood

socioeconomic status and race as predictors of adolescent ambulatory blood pressure and heart rate. *Soc Sci Med* 2006; 63: 1442–1453. https://doi.org/10.1016/j.socscimed.2006.03.019.

74. Mirzaei M, Taylor R, Morrell S, Leeder SR. Predictors of blood pressure in a cohort of school-aged children. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 624–629. https://doi.org/10.1097/ HJR.0b013e32828621c6.

75. Moore WE, Eichner JE, Cohn EM et al. Blood pressure screening of school children in a multiracial school district: the healthy kids project. *Am J Hypertens* 2009; 22: 351–356. https://doi. org/10.1038/ajh.2009.13.

76. de Moraes ACF, Carvalho HB, Siani A et al. Incidence of high blood pressure in children – effects of physical activity and sedentary behaviors: the IDEFICS study. *Int J Cardiol* 2015; 180: 165–170. https://doi.org/10.1016/j.ijcard.2014.11.175.

77. Moser DC, Giuliano Ide CB, Titski ACK et al. Anthropomet- ric measures and blood pressure in school children. *J Pediatr (Rio J)* 2013; 89: 243–249. https://doi.org/10.1016/j.jped.2012.11.006.

78. Mu J, Liu Z, Yang D et al. Baseline Na–Li counter-transport and risk of hypertension in children: a 10-year prospective study in Hanzhong children. J Hum *Hypertens* 2004; 18: 885–890. https:// doi.org/10.1038/sj.jhh.1001760.

79. Munthali RJ, Kagura J, Lombard Z, Norris SA. Childhood adiposity trajectories are associated with late adolescent blood pressure: birth to twenty cohort. *BMC Public Health* 2016; 16: 665. https://doi.org/10.1186/s12889-016-3337-x.

80. Musa DI, Williams CA. Cardiorespiratory fitness, fatness, and blood pressure associations in Nigerian youth. *Med Sci Sports Exerc* 2012; 44: 1978–1985. https://doi.org/10.1249/MSS. 0b013e31825ae19d.

81. Kim NY, Hong YM, Jung JW et al. The relationships of body mass index, waist-to-height ratio, and body fat percentage with blood pressure and its hemodynamic determinants in Korean adolescents: a school-based study. *Korean J Pediatr* 2013; 56: 526–533. https://doi.org/10.3345/kjp.2013.56.12.526.

82. Narang I, Manlhiot C, Davies-Shaw J et al. Sleep disturbance and cardiovascular risk in adolescents. *Can Med Assoc* J 2012; 184: E913–E920. https://doi.org/10.1503/cmaj.111589.

83. Kim N, Seo D-C, King MH, Lederer AM, Sovinski D. Long- term predictors of blood pressure among adolescents during an 18-month school-based obesity prevention intervention. *J Adolesc Health* 2014; 55: 521–527. https://doi.org/10.1016/j.jadohealth. 2014.04.011.

84. Normia J, Laitinen K, Isolauri E et al. Impact of intrauterine and post-natal nutritional determinants on blood pressure at 4 years of age. *J Hum Nutr Diet* 2013; 26: 544–552. https://doi. org/10.1111/jhn.12115.

85. Nowson CA, MacInnis RJ, Hopper JL et al. Association of birth weight and current body size to blood pressure in female twins. *Twin Res* 2001; 4: 378–384. https://doi.org/10. 1375/1369052012551.

86. Nur N, Cetinkaya S, Yilmaz A et al. Prevalence of hypertension among high school students in a middle Anatolian province of Turkey. *J Health Popul Nutr* 2008; 26: 88–94.

87. Odunaiya NA, Louw QA, Grimmer KA. Are lifestyle cardio- vascular disease risk factors associated with pre-hypertension in 15-18 years rural Nigerian youth? A cross sectional study. *BMC Cardiovasc Disord* 2015; 15: 144. https://doi.org/10.1186/ s12872-015-0134-x.

88. Peach H, Gaultney JF, Reeve CL. Sleep characteristics, body mass index, and risk for hypertension in young adolescents. *J Youth Adolesc* 2015; 44: 271–284. https://doi.org/10.1007/ s10964-014-0149-0.

89. Polderman J, Gurgel RQ, Barreto-Filho JAS et al. Blood pressure and BMI in adolescents in Aracaju, Brazil. *Public Health Nutr* 2011; 14: 1064–1070. https://doi.org/10.1017/S1368980010003666.

90. de Queiroz VM, Moreira PVL, de Vasconcelos THC, de Toledo Vianna RP. Prevalence and anthropometric predictors of high blood pressure in schoolchildren from João Pessoa – PB, Brazil. *Arq Bras Cardiol* 2010; 95: 629–634.

91. Ramos-Arellano LE, Benito-Damián F, Salgado-Goytia L et al. Body fat distribution and its association with hypertension in a sample of Mexican children. *J Invest Med* 2011; 59: 1116–1120 https://doi.org/10.2310/JIM.0b013e31822a29e1.

92. Relton CL, Pearce MS, O'Sullivan JJ. The relationship between gestational age, systolic blood pressure and pulse pressure in children. *J Hum Hypertens* 2008; 22: 352–357. https://doi. org/10.1038/sj.jhh.1002319.

93. Ribeiro RC, Lamounier JA, Oliveira RG, Bensenor IM, Lotufo PA. Measurements of adipocity and high blood pressure among children and adolescents living in Belo Horizonte. *Cardiol Young* 2009; 19: 436–440.

94. Savva SC, Tornaritis M, Savva ME et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular dis- ease risk factors in children than body mass index. *Int J Obes (Lond)* 2000; 24: 1453–1458. https://doi.org/10.1038/sj.ijo.0801401.

95. Sesso R, Franco MCP. Abnormalities in metalloproteinase pathways and IGF-I axis: a link between birth weight, hyperten- sion, and vascular damage in childhood. *Am J Hypertens* 2010; 23: 6–11. https://doi.org/10.1038/ajh.2009.200.

96. Sesso R, Barreto GP, Neves J, Sawaya AL. Malnutrition is associated with increased blood pressure in childhood. *Nephron Clin Pract* 2004; 97: c61–c66. https://doi.org/10.1159/000078402.

97. Setayeshgar S, Ekwaru JP, Maximova K et al. Dietary intake and prospective changes in cardiometabolic risk factors in children and youth. *Appl Physiol Nutr Metab* 2017; 42: 39–45. https://doi. org/10.1139/apnm-2016-0215.

98. Sharp TA, Grunwald GK, Giltinan KE et al. Association of anthropometric

measures with risk of diabetes and cardiovascular disease in Hispanic and Caucasian adolescents. *Prev Med* 2003; 37: 611–616. https://doi.org/10.1016/j.ypmed.2003.09.008.

99. Shirasawa T, Shimada N, Ochiai H et al. High blood pressure in obese and nonobese Japanese children: blood pressure measurement is necessary even in nonobese Japanese children. *J Epidemiol* 2010; 20: 408–412. https://doi.org/10.2188/jea.JE20090207.

100. Simonetti GD, Schwertz R, Klett M et al. Determinants of blood pressure in preschool children: the role of parental smoking. *Circulation* 2011; 123: 292–298. https://doi.org/10.1161/ CIRCULATIONAHA.110.958769.

101. Taal HR, Verwoert GC, Demirkan A et al. Genome-wide profiling of blood pressure in adults and children. *Hypertension* 2012; 59: 241–247. https://doi.org/10.1161/ HYPERTENSIONAHA.111.179481.

102. Taine M, Stengel B, Forhan A et al. Rapid early growth may modulate the association between birth weight and blood pressure at 5 years in the EDEN cohort study. *Hypertension* 2016; 68: 859–865. https://doi.org/10.1161/HYPERTENSIONAHA.116. 07529.

103. Tamai Y, Wada K, Tsuji M et al. Dietary intake of vitamin B12 and folic acid is associated with lower blood pressure in Japanese preschool children. *Am J Hypertens* 2011; 24: 1215–1221. https://doi.org/10.1038/ajh.2011.133.

104. Thiering E, Brüske I, Kratzsch J et al. Peak growth velocity in infancy is positively associated with blood pressure in school-aged children. *J Hypertens* 2012; 30: 1114–1121. https://doi.org/10. 1097/HJH.0b013e328352d699.

105. Vlajinac H, Miljus D, Adanja B et al. Blood pressure levels in 7 to 14-year-old Belgrade children. *J Hum Hypertens* 2003; 17: 761–765. https://doi.org/10.1038/sj.jhh.1001618.

106. Vohr BR, Allan W, Katz KH, Schneider KC, Ment LR. Early predictors of hypertension in prematurely born adolescents. *Acta Paediatr* 2010; 99: 1812–1818. https://doi.org/10.1111/j. 1651-2227.2010.01926.x.

107. Walker SP, Gaskin P, Powell CA et al. The effects of birth weight and postnatal linear growth retardation on blood pressure at age 11-12 years. *J Epidemiol Community Health* 2001; 55: 394–398.

108. Wang H, Necheles J, Carnethon M et al. Adiposity measures and blood pressure in Chinese children and adolescents. *Arch Dis Child* 2008; 93: 738–744. https://doi.org/10.1136/adc.2007. 127589.

109. Watts K, Bell LM, Byrne SM, Jones TW, Davis EA. Waist circumference predicts cardiovascular risk in young Australian children. *J Paediatr Child Health* 2008; 44: 709–715. https://doi. org/10.1111/j.1440-1754.2008.01411.x.

110. Wells JCK, Hallal PC, Reichert FF et al. Sleep patterns and television viewing in relation to obesity and blood pressure: evidence from an adolescent Brazilian birth cohort. *Int J Obes (Lond)* 2008; 32: 1042–1049.

https://doi.org/10.1038/ijo.2008.37.

111. Wells JCK, Hallal PC, Reichert FF et al. Associations of birth order with early growth and adolescent height, body composition, and blood pressure: prospective birth cohort from Brazil. *Am J Epidemiol* 2011; 174: 1028–1035. https://doi.org/10.1093/ aje/kwr232.

112. Wicklow BA, Becker A, Chateau D et al. Comparison of anthropometric measurements in children to predict metabolic syndrome in adolescence: analysis of prospective cohort data. *Int J Obes (Lond)* 2015; 39: 1070–1078. https://doi.org/10.1038/ijo. 2015.55.

113. Willig AL, Casazza K, Dulin-Keita A et al. Adjusting adiposity and body weight measurements for height alters the relation- ship with blood pressure in children. *Am J Hypertens* 2010; 23: 904–910. https://doi.org/10.1038/ajh.2010.82.

114. Xu T, Zhu G, Liu J, Han S. Gender-specific prevalence and associated risk factors of high normal blood pressure and hyper- tension among multi-ethnic Chinese adolescents aged 8-18 years old. *Blood Press* 2015; 24: 189–195. https://doi.org/10. 3109/08037051.2015.1025474.

115. Urbina E, Alpert B, Flynn J et al. Ambulatory blood pressure monitoring in children and adolescents: recommendations for standard assessment: a scientific statement from the American Heart Association – atherosclerosis, hypertension, and obesity in youth committee of the council on cardiovascular disease in the young and the council for high blood pressure research. *Hypertension* 2008; 52: 433–451. https://doi.org/10.1161/HYPERTENSION AHA.108.190329.

116. Butani L, Morgenstern BZ. Are pitfalls of oxcillometric blood pressure measurements preventable in children? *Pediatr Nephrol* 2003; 18: 313–318. https://doi.org/10.1007/s00467-003- 1075-7.

117. McEniery CM, Cockcroft JR, Roman MJ, Franklin SS, Wilkinson IB. Central blood pressure: current evidence and clinical importance. *Eur Heart J* 2014; 35: 1719–1725. https://doi.org/10. 1093/eurheartj/eht565.

118. de Onis M, Garza C, Onyango AW et al. WHO child growth standards. *Acta Paediatr* 2006; 95: 106. https://doi.org/10.1037/ e569412006-008.

119. Lifton RP. Molecular genetics of human blood pressure variation. *Science* 1996; 272: 676–680. https://doi.org/10.1126/ science.272.5262.676.

120. Raj M. Essential hypertension in adolescents and children: recent advances in causative mechanisms. *Indian J Endocrinol Metab* 2011; 15: 367. https://doi.org/10.4103/2230-8210.86981.

121. Barker DJ. In utero programming of chronic disease. *Clin Sci (Lond)* 1998; 95: 115–128.

122. Dharmashankar K, Widlansky ME. Vascular endothelial function and hypertension: insights and directions. *Curr Hypertens Rep* 2010; 12: 448–455. https://doi.org/10.1007/s11906-010-0150-2.

123. Park K, Wei J, Minissian M, Bairey Merz CN, Pepine CJ. Adverse pregnancy conditions, infertility, and future cardiovascular risk: implications for mother and child. *Cardiovasc Drugs Ther* 2015; 29: 391–401. https://doi.org/10.1007/s10557-015-6597-2.

124. Palinski W. Effect of maternal cardiovascular conditions and risk factors on offspring cardiovascular disease. *Circulation* 2014; 129: 2066–2077. https://doi.org/10.1161/CIRCULATIONAHA. 113.001805.

125. Turner RJ, Avison AR. Status variations in stress exposure: implications for the interpretation of research on race, socioeconomic status, and gender. *J Health Soc Behav* 2003; 44: 488–505. https://doi.org/10.2307/1519795.

126. Reilly JJ. Tackling the obesity epidemic: new approaches. *Arch Dis Child* 2006; 91: 724–726. https://doi.org/10.1136/adc. 2006.098855.

Chapter 3.

Multifactorial Correlates of Blood Pressure in South Asian Children in Canada: A Cross-Sectional Study[2]

3.1. Introduction

South Asians comprise approximately 25% of the world's global population [1] and represent a significant portion of the visible ethnic minority groups in countries such as Canada, the United Kingdom (UK) and the United States (US) [2–4.] Individuals of South Asian origin are known to be at increased risk of cardiovascular disease (CVD) relative to other ethnic groups in Western countries [5, 6]. These differences in CVD risk have also been shown to be present in South Asian children, suggesting that the risk differential in CVD risk factors and events experienced by this ethnic group starts from an early age [7].

One of the major physiological risk factors for CVD is high blood pressure (BP) or hypertension [8]. Hypertension is also associated with an increased risk for stroke and kidney disease [8]. Moreover, multiple studies have shown that high BP in childhood typically continues into adulthood [9] – including in South Asian populations [10]. These findings suggest that it is important to prevent hypertension in childhood in order to address the potential cardiovascular and metabolic sequelae later in life.

In South Asian children, studies have demonstrated an increased prevalence of hypertension or higher BP levels relative to other ethnic groups [11,12]. While there is evidence suggesting a disproportionately higher BP burden for South Asians, the exact factors implicated are relatively unclear. Given the fact that causes of high BP are known to be multifactorial [8], it is important to understand the various risk factors that might be responsible for the increased risk of high BP in South Asian children in general. Using a range of multifactorial variables (i.e., variables across a range of different factors) that

---

[2]Fowokan A, Punthakee Z, Waddell C, Rosin M, Morrison KM, Gupta M, Rangarajan S, Teo K, Lear S. Multifactorial correlates of blood pressure in South Asian children in Canada: a cross-sectional study. *BMJ Open.* 2019;9(4): e027844.

were identified in a recently published systematic review of children to be correlated with BP and hypertension in other child population groups [13], this study therefore aims: 1) to explore the associations between physiological (relating to biology), lifestyle (relating to behaviour) and social factors (relating to conditions in which people live, attend school, grow, and develop) and BP in South Asian children; and 2) to identify the most important aggregate correlates of BP in South Asian children.

3.2. Methods

3.2.1. Study Design

Participants included in this study were recruited as part of the Research in International Cardiovascular Health – Lifestyles, Environments and Genetic Attributes in Children and Youth (RICH-LEGACY) study. This cross-sectional study is designed to investigate risk factors for CVD across South Asian children in Canada. The study was approved by the Simon Fraser University Research Ethics Board (REB), Providence Health Care REB, and the Hamilton Integrated REB. Parents of participants provided written informed consent, while participants assented to take part in the study.

3.2.2. Recruitment

Elementary school and high-school children (n= 762) were recruited using community-based methods in two Canadian cities (Brampton, Ontario and Surrey, British Columbia) by convenience sampling between 2012 and 2016. Letters were first sent to school boards to identify elementary schools with a high rate of South Asian enrolment. Once schools were identified, packages containing an invitation letter, a RICH-LEGACY study description and consent forms were sent to parents/guardians of children enrolled in the identified schools. Information stands were also placed at the participating elementary schools before and after school hours to reach out to parents with more information about the study. Additionally, the study was advertised through venues used by South Asian groups including newspapers, local television stations, community centres, worship centres and festivals. Inclusion criteria included: children (in elementary or high school) having at least three grandparents of South Asian origin; and participants being able to provide consent (parents) and assent (children). Research assistants fluent in Hindi and Punjabi were responsible for participant recruitment and data collection. The research assistants who were involved in the measurements all undertook training together through simulator sessions and were retrained if variations in measurement protocol were observed by the research coordinator. This process was repeated for a few days to ensure accuracy and consistency amongst the research assistants in the assessment of the measurements collected in this study. In addition, written materials (including consent forms) were provided in English, Punjabi, Hindi and Urdu as needed.

3.2.3. Participant Assessment

Participants for the RICH-LEGACY study were assessed regarding socio-demographic variables including age, sex and parental education. In certain cases, parents or guardians helped complete certain sections of the child's questionnaire. Children's perception of body image was assessed using Stunkard's silhouettes, a rating scale from one to nine with increases related to increased silhouette size [14] that assesses perception of size and body dissatisfaction. This figure rating scale has been shown to be a valid indicator of determining weight status in children [15]. Dietary practices were assessed using the childhood feeding questionnaire [16]. Exposure to bullying was assessed by asking participants if they had experienced bullying or violence at school. This variable was assessed because of its role as a known stressor in children and its possible impact on pathways known to be involved in BP regulation such as the hypothalamic-pituitary-adrenal (HPA) axis [17]. Additionally, level of acculturation was assessed using the Acculturation Rating Scale for Mexican Americans-II (ARSMA- II) adapted for use in South Asians by Stigler *et al* [18]. This scale assesses an individual's identification with their heritage based on different domains including language preferences, media preferences, and preferences regarding food and other consumer goods using 24 questions [18]. The adapted questionnaire is grouped into two scales: the Western scale and the traditional scale. The traditional acculturation score measures children's acceptance of traditional Indian cultural attributes while the Westernized acculturation score measures the degree to which South Asian children identify with Western culture.

Participants completed a semi-quantitative food frequency questionnaire (FFQ) that assessed intake of fruits and vegetables and fast foods. The FFQ was adapted from the INTERHEART FFQ, which was validated in an international cohort that included

South Asians [19]. Physical activity was assessed using a standardized questionnaire that quantified sports and other activities including leisure, household chores and sedentary factors (screen time and homework) during school and outside of school over the past month. All activities were then expressed as metabolic-equivalent-of-task (MET) minutes. Self-reported exposure to second-hand smoke was assessed to characterize children's passive exposure to smoking and defined as a minimum of five consecutive minutes during which inhalation of other people's smoke occurs. Hand-grip strength, a measure of muscular strength, was measured on the non-dominant hand by study personnel with a Jamar dynamometer utilizing standardized protocol [20].

3.2.4. Anthropometric Characteristics

Height was measured to the nearest 0.1 cm using a right angle triangle and a calibrated wall mounted scale. Weight was measured to the nearest 0.1 kg with the participant in light clothing using an electronic scale. Body mass index (BMI) was first calculated from weight in kilograms divided by height in meters squared before being converted to z-scores using WHO growth references for young people aged 5-19 years [21].

Waist circumference (WC) was recorded in centimetres as the average of two measures taken halfway between the lower rib margin and the iliac crest against the skin following a normal expiration. Waist circumference was assessed using non-stretching measuring tape by trained team members. Waist-to-height ratio (WtHR) was then calculated by dividing WC by height. Both WC and WtHR were transformed to z scores using published lambda-mu-sigma (LMS) values for age and sex based on the third US National Health and Nutrition Examination Survey (NHANES III – 1988-1994 and 1999-2012 cycles) [22]. Transforming the anthropometric measures to z-scores allowed for the standardized comparisons across populations of children of similar ages and sex.

3.2.5. Blood Pressure and Heart Rate

Blood pressure and heart rate were measured in the left arm using the Omron HEM-711DLX automated BP monitor with appropriate sized cuffs following 10 minutes of seated rest. Three BP and heart rate measures were taken over a 10-minute period and the average of the three was recorded. Subsequently, BP was transformed to standard deviation scores and percentiles adjusted for age, sex and height according to the fourth National High Blood Pressure Education Program (NHBPEP) working group in children and adolescents [23]. Systolic and diastolic hypertension were defined using the NHBPEP recommendations as average systolic BP or diastolic BP equal to or greater than the 95th percentile for sex, age and height.

3.2.6. Parental Variables

Parents of the children recruited for this study provided information on parental (father's and mother's) education. In a smaller subset of the South Asian children (n=271), parental history of hypertension (yes or no) was assessed in order to explore the potential impact of heritable factors on children's BP z-scores and hypertension. Father's education was used as a proxy variable for socioeconomic status in this study. Fathers' education levels were categorized as: those with no formal education; those with primary/secondary school education; those with a trade school degree/diploma; and those with a college or university degree. Parent's smoking status was self-reported and categorized as non-smoker, former smoker or current smoker.

3.2.7. Statistical Analysis

All continuous variables were examined using P-P plots and found to be normally distributed. For descriptive analysis, continuous variables were presented as means and standard deviations while categorical variables were reported as counts and percentages. Independent t-test analysis was used to assess sex differences in continuous variables, while chi-square tests were used to assess sex differences in categorical variables.

To explore the associations with systolic and diastolic BP across the range of physiological, behavioural and sociodemographic variables, unadjusted linear regression was used. These models were then adjusted for potential confounding effect of child age, sex and father's education. These confounders were selected based on their well – documented independent associations with the outcome variable in research studies [11,13]. Although, the conversion of to z-scores provides age and sex adjusted data, we chose to still include age and sex as confounders to adjust for potential residual effects unaccounted for by the reference chart used in this study. Similarly, unadjusted and adjusted (age, sex and father's education) logistic regression analysis was used to explore clinically-relevant associations among the multifactorial variables with systolic and diastolic hypertension. While age and sex were identified as potential confounders in the association between the other variables assessed in this study with BP and hypertension, we also wanted to examine their independent associations with BP and hypertension. To do this, they were each removed from the list of confounders we adjusted for when exploring their effect on BP z-scores and hypertension (i.e., sex was adjusted for age and father's education, while age was adjusted for sex and father's education.).

To address the second study objective, stepwise multiple linear regression analyses were used to identify the combination of risk factors that best explained the variance in BP in South Asian children. The stepwise regression method enables the identification of the aggregate combination of correlates that has the highest contributory effect to the outcome variable. Specifically, for this analysis, we utilized the backward method to select the list of multifactorial correlates that provide significant contribution to the outcome (systolic and diastolic BP z-scores) using an entry criterion of $p < 0.05$ and a removal criterion of $p > 0.10$. The specific list of correlates (age, sex, height, weight, heart rate, BMI z-score, WC z-score, WHtR z-score, parental history of hypertension, parental education, exposure to bullying and violence, traditional and western acculturation scores, physical activity in school and outside school, dietary variables and second-hand smoking) considered for introduction in the backward stepwise regression model were chosen *a priori* based on evidence from the literature [13] and whether they had a p value <0.05 in unadjusted analysis. Using the aforementioned criteria, the following variables were considered in step-wise regression analysis: age, sex, height, weight, BMI z-score, WC z-score, WHtR z-score, heart rate, western acculturation score, child's perception of body image, and grip strength. In addition to these variables, father's education, daily intake of fast foods and total daily intake were considered in diastolic BP z-score models. The adjusted R squared value for each model provides the combined contribution of the variables in the model to the variance in BP z-scores. The full list of variables initially identified from literature search were also considered in logistic regression models with hypertension. Statistical analysis was done using Statistical Package for the Social Sciences (SPSS) version 24.0. P values <0.05 were considered statistically significant. This study was written in line with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines [24].

3.3. Results

This study included 360 boys (47%) and 402 girls ranging from 5.8 to 17.0 years (mean age 9.5 ± 3.0 years), with no statistically significant difference observed for age by sex (Table 3.1). The prevalence of systolic hypertension in this population was 12%. South Asian boys were more physically active outside school than girls (p=0.04); had higher WC z-score (p<0.001); had higher WHtR z-score (p=0.02); had lower heart rate (p=0.047); had higher systolic BP z-scores (p=0.001); had higher prevalence of systolic hypertension (p=0.01); had lower traditional acculturation score (p=0.02); and had significantly higher exposure to bullying and violence at school (p=0.025).

Table 3.1. Sociodemographic, anthropometric, risk factor characteristics of South Asian children stratified by sex.

	Total (n=762)	Boy (n=360)	Girl (n=402)	p value
Age (years)	9.5 ± 3.0	9.3 ± 2.8	9.7 ± 3.1	0.09
Paternal education				0.92
No formal education	5 (1%)	3 (1%)	2 (1%)	
Primary/Secondary education	247 (34%)	115 (34%)	132 (35%)	
Trade school	21 (3%)	9 (3%)	12 (3%)	
College/university	444 (62%)	209 (62%)	235 (62%)	
Maternal education				0.363
No formal education	5 (1%)	4 (1%)	1 (0%)	
Primary/Secondary education	223 (30%)	103 (30%)	120 (31%)	
Trade school	6 (1%)	4 (1%)	2 (1%)	
College/university	503 (68%)	235 (68%)	268 (69%)	
Acculturation score (western)	34.8 ± 4.7	34.6 ± 4.62	34.9 ± 4.74	0.426
Acculturation score (traditional)	26.7 ± 4.43	26.3 ± 4.35	27.1 ± 4.48	0.02
Daily physical activity in school (METmins/day)	35.7 ± 25.8	36.8 ± 27.0	34.8 ± 24.7	0.288
Daily physical activity outside school (MET mins/day)	15.9 ± 33.9	18.5 ± 31.3	13.5 ± 35.9	0.04
Daily intake- servings of fruit and vegetables (daily mean intake)	3.16 ± 1.86	3.11 ± 1.81	3.21 ± 1.91	0.485
Daily intake- servings of fast foods (daily mean intake)	0.91 ± 0.78	0.86 ± 0.59	0.97 ± 0.91	0.067
Total daily intake- servings	12.0 ± 4.48	12.2 ± 4.9	11.8 ± 4.1	0.243
Exposure to bullying/violence at school				0.025
Yes	233 (34%)	126 (38%)	107 (30%)	
No	459 (66%)	207 (62%)	252 (70%)	

Exposure to second-hand smoking*				0.616
None	712 (94%)	336 (94%)	376 (94%)	
1-2 times/week	33 (4%)	16 (5%)	17 (4%)	
3-6 times/week	5 (1%)	2 (1%)	3 (1%)	
At least once a day	7 (1%)	5 (1%)	2 (1%)	
2-3 times/day	1 (0%)	0 (0%)	1 (0%)	
Mother's history of hypertension				0.047
Yes	12 (4%)	9 (7%)	3 (2%)	
No	280 (96%)	128 (93%)	152 (98%)	
Father's history of hypertension				0.979
Yes	30 (10%)	14 (10%)	16 (10%)	
No	260 (90%)	122 (90%)	138 (90%)	
Height (cm)	138.3 ± 16.5	139.1 ± 17.6	137.7 ± 15.5	0.22
Weight (kg)	36.5 ± 15.8	36.9 ± 16.5	36.1 ± 15.3	0.46
BMI Z score	0.48 ± 1.44	0.57 ± 1.61	0.40 ± 1.28	0.11
WC Z score	-0.06 ± 1.23	0.11 ± 0.36	-0.21 ± 1.24	<0.001
WHtR Z score	-0.38 ± 1.24	-0.27 ± 1.27	-0.48 ± 1.21	0.02
Heart rate	87 ± 12	86 ± 12	87 ± 13	0.047
sBP Z score	0.57 ± 0.97	0.70 ± 0.99	0.46 ± 0.95	0.001
dBP Z score	0.37 ± 0.71	0.35 ± 0.68	0.39 ± 0.73	0.41
sBP (non-transformed)	109 ± 11	111 ± 12	107± 10	<0.001
dBP (non-transformed)	65 ± 8	65 ± 8	65 ± 8	0.849
Systolic hypertension	90 (12%)	54 (15%)	36 (9%)	0.01
Diastolic hypertension	31 (4%)	13 (4%)	18 (5%)	0.55

*Exposure defined as a minimum of five consecutive minutes during which inhalation of other people's smoke occurs
BP=Blood pressure, BMI=body mass index, WC= waist circumference, WHtR= waist to height ratio, sBP= systolic blood pressure, dBP= diastolic blood pressure

3.3.1. Correlates of Systolic BP and Systolic Hypertension

In unadjusted linear regression analysis with systolic BP z-scores, weight (kg) (β= 0.005, 95% CI= 0.001, 0.01, p=0.022), BMI z-score (β= 0.289, 95% CI= 0.246, 0.333, p<0.001), WC z-score (β= 0.266, 95% CI= 0.213, 0.319, p<0.001), WHtR z-score (β= 0.271, 95% CI= 0.219, 0.324, p<0.001), heart rate (beats per minute) (β= 0.019, 95% CI= 0.015, 0.023, p<0.001), and the child's perception of their body image (using Stunkard's silhouettes) (β= 0.136, 95% CI= 0.083, 0.189, p<0.001) were all found to be positively associated with systolic BP z-score. In contrast, we found that compared to males, females had lower systolic BP z-score (β= -0.246, 95% CI= -0.385, -0.108, p<0.001). Similarly, age (years) (β= -0.060, 95% CI= -0.084, -0.037, p<0.001), children's western acculturation score (β= -0.021, 95% CI= -0.036, -0.006, p=0.007) and height (cm) (β= -0.006, 95% CI= -0.010, -0.002, p=0.007) were negatively associated with systolic BP z-score. After adjustment for confounders, the association between western acculturation attenuated and became non-significant, while the association observed between height and systolic BP z-score became positive. Associations between children's grip strength and daily physical activity in school with systolic BP z-score also became significant upon adjustment (Table 3.2).

In stepwise regression analysis, the combination of age, sex, BMI z-score, heart rate and weight were observed to be the most important correlates of systolic BP z-score, accounting for 30% of the systolic BP z-score variance of South Asian children (Table 3.3).

In unadjusted logistic regression analysis, female sex was associated with lower odds of developing systolic hypertension (odds ratio (OR) = 0.56, 95% CI= 0.36, 0.87, p=0.011). Associations were also observed with: weight (kg) and systolic hypertension (OR= 1.02, 95% CI= 1.01, 1.04, p<0.001); BMI z-score and systolic hypertension (OR= 2.22, 95% CI= 1.84, 2.68, p<0.001); WC z-score and systolic hypertension (OR= 2.65, 95% CI= 2.06, 3.43, p<0.001); and WHtR z-score and systolic hypertension (OR= 2.47, 95% CI= 1.95, 3.13, p<0.001). Similarly, associations were observed between heart rate (beats per minute) and systolic hypertension (OR=1.04, 95% CI= 1.02, 1.06, p<0.001), child's perception of body image and systolic hypertension (OR= 1.50, 95% CI= 1.25, 1.79, p<0.001) and western acculturation score with systolic hypertension (OR= 0.95, 95% CI=0.90, 1.00, p=0.03). Upon adjustment for confounders, the associations between western acculturation score and systolic hypertension attenuated and became non-significant. In contrast, the association between grip strength and systolic hypertension became significant upon adjustment (Figure 3.1).

Table 3.2. Adjusted linear regression between multifactorial risk factors with systolic and diastolic BP z-scores

	Systolic BP z score	**Diastolic BP z score**
Age[a]	-0.054 (-0.078, -0.029), p<0.001	-0.057 (-0.075, -0.039), p<0.001
Female sex (vs Male)[b]	-0.208 (-0.350, -0.067), p=0.004	0.078 (-0.023, 0.179), p=0.132
Height	0.022 (0.011, 0.033), p<0.001	0.007 (-0.001, 0.015), p=0.077
Weight	0.047 (0.040, 0.055), p<0.001	0.022 (0.016, 0.027), p<0.001
BMI z score	0.292 (0.249, 0.336), p<0.001	0.160 (0.127, 0.193), p<0.001
WC z score	0.273 (0.219, 0.326), p<0.001	0.137 (0.098, 0.177), p<0.001
WHtR z score	0.289 (0.236, 0.342), p<0.001	0.153 (0.114, 0.192), p<0.001
Heart rate	0.016 (0.010, 0.022), p<0.001	0.015 (0.011, 0.019), p<0.001
Acculturation (western score)	-0.010 (-0.026, 0.006), p=0.211	-0.005 (-0.016, 0.006), p=0.373
Acculturation (traditional score)	0.010 (-0.006, 0.026), p=0.227	0.003 (-0.008, 0.015), p=0.582
Child's perception of body	0.183 (0.128, 0.239), p<0.001	0.104 (0.064, 0.144), p<0.001

image		
Exposure to bullying/violence at school	0.021 (-0.138, 0.181), p=0.794	-0.071 (-0.183, 0.042), p=0.218
Father's smoking status	0.118 (-0.056, 0.292), p=0.184	0.082 (-0.053, 0.218), p=0.233
Exposure to second hand smoke	-0.052 (-0.240, 0.136), p=0.587	0.018 (-0.117, 0.152), p=0.795
Father's history of hypertension	-0.127 (-0.484, 0.230), p=0.484	-0.063 (-0.336, 0.209), p=0.648
Mother's history of hypertension	-0.003 (-0.524, 0.518), p=0.991	0.354 (-0.042, 0.750), p=0.079
Grip strength (non-dominant hand)	0.025 (0.007, 0.043), p=0.007	0.006 (-0.007, 0.019), p=0.381
Daily physical activity in school (METmins/day)	0.005 (0.002, 0.008), p=0.003	0.003 (0.001, 0.005), p=0.009
Daily physical activity outside school (METmins/day)	0.001 (-0.001, 0.003), p=0.363	0.000 (-0.002, 0.002), p=0.994
Daily intake- fruit and vegetables (daily mean intake)	-0.008 (-0.049, 0.033), p=0.717	-0.011 (-0.040, 0.018), p=0.466
Daily intake-fast foods (daily mean intake)	0.004 (-0.086, 0.093), p=0.937	-0.053 (-0.117, 0.011), p=0.104

Model adjusted for age, sex and father's education
Values presented are β (95% confidence intervals), and p values
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure, MET=Metabolic equivalent of task
[a]Age was adjusted for sex and father's education
[b]Sex was for adjusted for age and father's education

Table 3.3. Stepwise linear regression analysis showing the aggregate correlates of BP z-score in South Asian children

Stepwise multiple linear regression models					
	Variable	**B**	**95%**	**P value**	**Adjusted R^2**
Systolic BP z-score	Child's age	-0.132	-0.202 -0.062	<0.001	
	Sex	-0.293	-0.461, -0.126	0.001	
	BMI z-score	0.125	0.022, 0.228	0.017	
	Heart rate	0.014	0.007, 0.021	<0.001	
	Weight	0.027	0.012, 0.041	<0.001	
					0.294
Diastolic BP z-score	Child's age	-0.027	-0.048, -0.007	0.01	
	BMI z-score	0.125	0.081, 0.170	<0.001	
	Heart rate	0.015	0.010, 0.021	<0.001	
	Daily fast food intake	-0.013	-0.028, 0.001	0.072	
					0.228

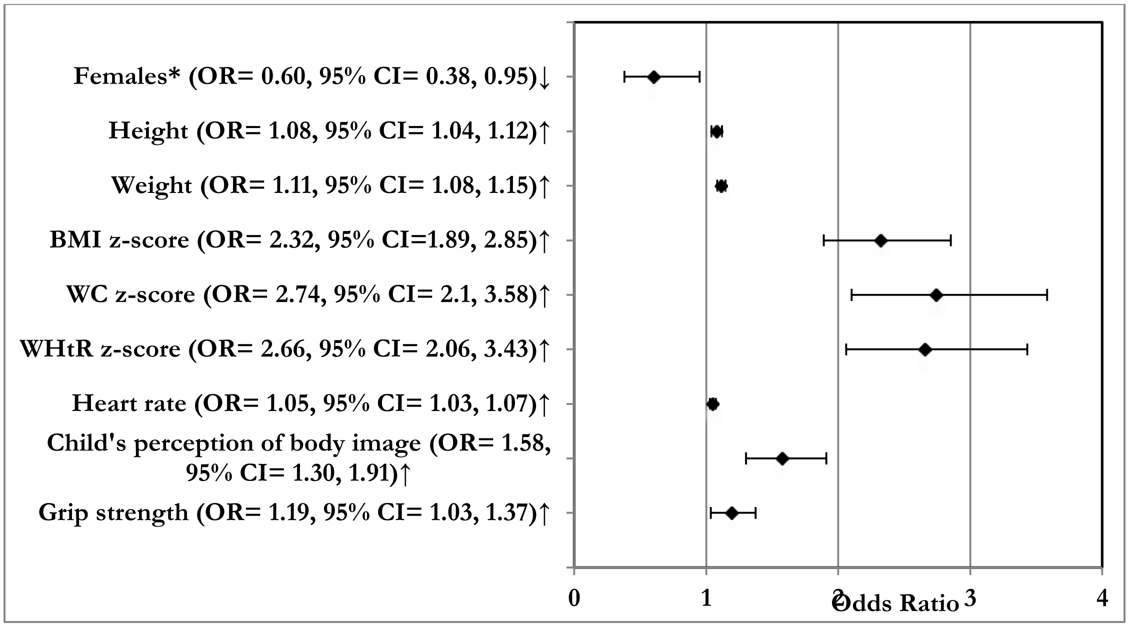
BMI=body mass index, BP= blood pressure

3.3.2. Correlates of Diastolic BP and Diastolic Hypertension

In unadjusted linear regression analysis of multifactorial variables with diastolic BP z-score, negative associations with diastolic BP z-score were observed between age (years) (β= -0.061, $p<0.001$), height (cm) (β= -0.009, $p<0.001$), western acculturation score (β= -0.018, p=0.007), fathers' level of education (β= -0.054, p=0.047), total daily food intake (β= -0.016, p=0.005), fast foods (β= -0.065, p=0.048) and grip strength (kg) (β= -0.019, $p<0.001$). Conversely, significant positive associations with diastolic BP z-score were observed between heart rate (β= 0.018, $p<0.001$), BMI z-score (β= 0.156, $p<0.001$), WC z-score (β= 0.120, $p<0.001$), WHtR z-score (β= 0.128, $p<0.001$), and children's perception of their body image (using Stunkard's silhouettes) (β= 0.053, p=0.007). After adjustment for confounders the association between height, western acculturation score, father's level of education, total daily food intake, fast food consumption and grip strength attenuated and became non-significant (Table 3.2).

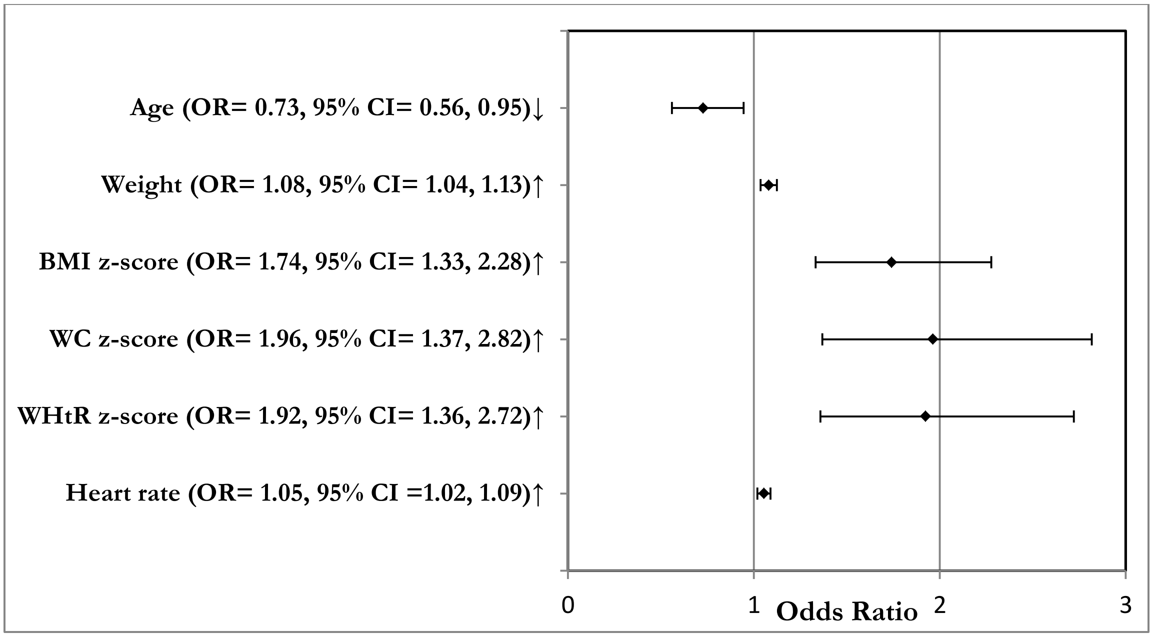
In stepwise regression analysis, the combination of age, BMI z-score, heart rate and daily intake of fast foods were observed to be the most important aggregate correlates of diastolic BP z-score, accounting for 23% of the diastolic BP z-score variance of South Asian children (Table 3.3).

In unadjusted logistic regression analysis, associations were observed between age (years) (OR= 0.71, 95% CI= 0.55, 0.92, p=0.01); height (OR= 0.97, 95% CI= 0.94, 1.00, p=0.04); BMI z-score (OR= 1.68, 95% CI= 1.31, 2.17, $p<0.001$); WC z-score (OR= 1.89, 95% CI= 1.32, 2.70, p=0.001); WHtR z-score (OR= 1.77, 95% CI= 1.26, 2.47, p=0.001); heart rate (beats per minute) (OR=1.06, 95% CI= 1.03, 1.10, $p<0.001$) and grip strength (kg) (OR= 0.92, 95% CI= 0.86, 0.99, p=0.024) with diastolic hypertension. Upon adjustment for confounders, the association between height, grip strength and diastolic hypertension attenuated and became non-significant (Figure 3.2).



Model adjusted for age, sex and father's education
Values presented are odds ratio (95% confidence intervals)
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio
*compared to males
↑=positive association with hypertension; ↓= negative association with hypertension

Figure 3.1. Adjusted odds ratio for the association between the multifactorial variables with systolic hypertension



Model adjusted for age, sex and father's education
Values presented are odds ratio (95% confidence intervals)
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure
↑=positive association with hypertension; ↓= negative association with hypertension

Figure 3.2. Adjusted odds ratio for the association between the multifactorial variables with diastolic hypertension

3.4. Discussion

This study provides information on a range of correlates of systolic and diastolic BP z-scores in a population of South Asian children. While results from unadjusted models highlight the presence of a multifactorial relationship for BP and hypertension, the disappearance of most of the social and lifestyle risk factors upon adjustment highlights the contribution of variables such as age, sex, adiposity, height, heart rate, and grip strength to the risk of elevated BP and hypertension in South Asian children.

It is well documented that the burden of hypertension has precipitously increased in the pediatric population [25]. In addition, some studies have documented higher prevalence of hypertension in certain ethnic groups such as South Asians [11]. Although our convenience sample was non-representative given that sampling was restricted to two Canadian cities, the prevalence of hypertension in our study at 12% is consistent with age-, sex- and height-adjusted estimates from Jafar *et al* [11] using a nationally-representative survey of Pakistani children age 5-14 years, but higher than the 5.2% prevalence found in one cross-sectional study of Indian children ages 5-12 years [26]. Our estimates also appear higher than estimates from Canadian children ages 6-19 years in the general population where only 7% of children were found to have hypertension and prehypertension [27]. When stratified by sex, we found significantly higher rates were observed for boys at 15% compared to girls at 9%. This is consistent with results from studies in other children which have reported higher hypertension prevalence in boys [28, 29], and results from the regression analysis which found female sex to be associated with lower odds of hypertension. This risk differential has been attributed to the presence of an anti-inflammatory immune profile in females and pro-inflammatory profile in males [30] – underscoring the potential for intervention efforts aimed at addressing sex-based disparities.

Consistent with research conducted in South Asian children [11,31] and research conducted in other childhood populations of different ethnicities [28,32–36], we observed positive associations between measures of adiposity and BP and hypertension after adjusting for covariates. The consistency of the association observed across the range of adiposity metrics assessed underscores the significant contribution of increasing adiposity to the prevalence of hypertension in South Asian children. Moreover, the positive association between grip strength (a measure of muscle strength) with systolic BP z-score and hypertension upon adjustment in this study raises questions about the benefits of strength training in children. The benefits of physical activity including aerobic exercise in relation to hypertension remain clear; however, the benefits of strength training in relation to hypertension risk, relative to the benefits of aerobic exercise, merit further study [37]. It is also unclear what might be responsible for the positive effect observed between grip strength and systolic BP z-score; however, findings from our study appear consistent with studies which have explored this association in Chinese [38] and American children [39].

The consistent association between adiposity and hypertension, including the higher prevalence of hypertension in this population, reinforces that these phenomena are connected through a range of complex pathways. Some of these pathways involve the activation of the renin-angiotensin-aldosterone system (RAAS) or sympathetic nervous system. Specifically, the South Asian phenotype of higher body fat [7]—especially the visceral type which has been identified in adults [6]—when compared to their White peers, could activate the formation of pro-inflammatory cytokines such as Interleukin 6 (IL-6) which results in physiological changes that could lead to endothelial and vascular dysfunction through the development of insulin resistance [40], in turn increasing predisposition for hypertension. The positive association between height and BP in this population could be explained by cerebral perfusion requirements where higher BP is needed in taller people to achieve optimal cerebral perfusion owing to hydrostatic pressure differences in taller and shorter individuals [41]. However, more research in South Asian children is warranted to corroborate our findings given the difference observed in direction of association in unadjusted and adjusted models.

The positive association we found between the child's perception of body image and BP may be due to this variable mirroring children's weight status or conversely, being a marker for a graded increase in stress levels, owing to societal criticism of fatter body types, which could have insidious effects for hypertension risk through its impact on the neuro-endocrine system [42]. Additionally, a range of social and lifestyle variables were found to be associated with BP z-score in unadjusted analysis but became non-significant upon adjustment for confounders. While results from unadjusted associations may demonstrate links between risk factor and outcome, the disappearance of the association upon adjustment for socio-demographic variables highlights the links between these variables and suggests that the pathway linking these factors with BP might be interdependent.

The stepwise regression model shows that correlates from this study explained only about 30% of the variance of systolic BP z-score and 23% of the variability of diastolic BP z-scores. It is possible that some of this unexplained variance might be explained by genetics, as it has been suggested that about 30-60% of the variance in BP may be heritable [43, 44]. Yet the lack of association between parental hypertension and child BP in the subset of parents of participants who provided this data would appear to contradict these findings for this population of South Asian children. However, it is likely that the subset of parents of child participants who provided this information might not be completely representative of the entire cohort, thereby biasing the results. Still, even accounting for potential genetic contributions, a significant amount of the BP variance remains unexplained. More research is needed to provide insight regarding the contributory effects of other potential variables that might contribute to risk of elevated BP in South Asian children.

Notably, null associations were also observed for certain variables in this study that have been found to be significantly associated with BP and hypertension in other child populations. For example, parental history of hypertension, dietary factors (such as consumption of fruit and vegetables) and exposure to second hand smoking have been linked in other studies to child BP but had no significant impact in this study. This could be reflective of the potential biases associated with using self-reports or may highlight how interactions between genes and environment/lifestyle shape risk factor susceptibilities – underscoring the need for more ethnic-based and ethnic comparison studies when exploring risk associations.

3.4.1. Study Limitations

This study has limitations. First, although we sought to recruit a representative sample of urban South Asian children, it was not a random sample. However, there is likely to be minimal effect on the relationships between the ranges of risk factors evaluated in this study. Second, the statistical modelling utilised in this study might limit the ability to infer causal associations between the risk factor variables and long term CVD risk in South Asian children. This is largely attributed to limitations of stepwise linear regression models which tend to favour the inclusion of proximal causes over distal ones. Robust frameworks such as those used to model causal connections in observational studies might eliminate this limitation by fully capturing the totality of both proximal and distal risk factors for hypertension in South Asian children. Third, potential recall biases may have occurred as a result of using self-report data for some of the variables including diet and physical activity measures. Fourth, the use of father's education as a measure of socioeconomic status poses limitations. Variables like household income would have been preferred; however, only a subset of participants provided data on household income, thus its use would have excluded a significant portion of children in this study. However, as a means to confirm the results, we separately adjusted for mother's education and no deviation in study results was observed. Last, the lack of data collection on sexual maturity status could potential confound the study results obtained here. However, the adjustment for age in this study, which acts as a proxy variable for sexual maturity, might help mitigate the bias. These limitations are in part addressed by strengths of this study which lies in its large sample size of South Asian children and in the wide range of risk factors examined.

3.4.2. Implications

Our findings underscore a range of factors that may contribute to risk of elevated BP and hypertension in South Asian children. Consequently, public health interventions – that emphasize prevention through population-based health education and related programs and that encourage lifestyle modifications considering unique cultural contexts – may have significant potential in addressing the burden of hypertension in this population. There are also implications for clinical settings. Specifically, our findings suggest that while South Asian children may benefit from interventions aimed at reducing obesity to address the comparatively higher burden of hypertension in this population, there are certain sub-groups who could benefit from more targeted preventive interventions in primary care settings – such as males, children with increased adiposity, taller children, children with increased heart rate, or children with a combination of these factors.

3.5. Conclusion

In this group of South Asian children, we found associations between a range of physiological, social and lifestyle factors with BP z-scores and hypertension. However, upon adjustment for confounders, physiological variables such as age, sex, height, adiposity and heart rate remained consistently associated with BP and hypertension, and provided the strongest explanatory effect for the variance in BP. Given the sequelae associated with elevated BP, including BP tracking from childhood into adulthood, these results provide evidence on modifiable risk factors that might be targeted by prevention strategies in primary care to reduce the burden of high BP and hypertension in South Asian children.

3.6. References

1. Population Reference Bureau. 2017 World Population Data Sheet. PRB's 2017 World Population Data Sheet.

2. Statistics Canada. Immigration and Ethnocultural Diversity in Canada. National Household Survey, 2011. National Household Survey, 2011. doi:99-010-X2011001

3. UK Office for National Statistics. Ethnicity and National Identity in England and Wales. Http://Www.Ons.Gov.Uk.

4. Hoeffel EM, Rastogi S, Kim MO, Shahid H. The Asian Population: 2010. *2010 Census Briefs*. 2012;(March):1-23.

5. Anand SS, Yusuf S, Vuksan V, et al. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE). *Lancet*. 2000;356(9226):279-284. doi:10.1016/S0140-6736(00)02502-2

6. Lear SA, Humphries KH, Kohli S, Chockalingam A, Frohlich JJ, Birmingham CL. Visceral adipose tissue accumulation differs according to ethnic background: Results of the Multicultural Community Health Assessment Trial (M-CHAT). *Am J Clin Nutr*. 2007;86(2):353-359.

7. J Eyre EL, Duncan MJ, Nevill A. South Asian Children Have Increased Body Fat in Comparison to White Children at the Same Body Mass Index. doi:10.3390/children4110102

8. WHO. *A Global Brief on Hypertension*.; 2013. doi:10.1136/bmj.1.4815.882-a

9. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: A systematic review and meta-regression analysis. *Circulation*. 2008;117(25):3171-3180. doi:10.1161/CIRCULATIONAHA.107.730366

10. Soudarssanane M, Mathanraj S, Sumanth M, Sahai A, Karthigeyan M. Tracking of blood pressure among adolescents and young adults in an urban slum of puducherry. *Indian J Community Med*. 2008;33(2):107-112. doi:10.4103/0970-0218.40879

11. Jafar TH, Islam M, Poulter N, et al. Children in South Asia have higher body mass-adjusted blood pressure levels than white children in the United States: a comparative study. *Circulation*. 2005;111(10):1291-1297. doi:10.1161/01.CIR.0000157699.87728.F1

12. Henderson EJ, Jones CHD, Hornby-Turner YC, Pollard TM. Adiposity and blood pressure in 7- to 11-year-old children: Comparison of British Pakistani and white British children, and of British Pakistani children of migrant and British-born mothers. *Am J Hum Biol*. 2011;23(5):710-716. doi:10.1002/ajhb.21204

13. Fowokan AO, Sakakibara BM, Onsel N, et al. Correlates of elevated blood

pressure in healthy children: a systematic review. *Clin Obes*. July 2018. doi:10.1111/cob.12271

14. Stunkard AJ. Use of the Danish Adoption Register for the study of obesity and thinness. *Res Publ Assoc Res Nerv Ment Dis*. 1983;60:115-120. https://ci.nii.ac.jp/naid/10025281459/. Accessed August 8, 2018.

15. Lo WS, Ho SY, Mak KK, Lam TH. The Use of Stunkard's Figure Rating Scale to Identify Underweight and Overweight in Chinese Adolescents. *PLoS One*. 2012;7(11). doi:10.1371/journal.pone.0050017

16. Birch L., Fisher J., Grimm-Thomas K, Markey C., Sawyer R, Johnson S. Confirmatory factor analysis of the Child Feeding Questionnaire: a measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. *Appetite*. 2001;36(3):201-210. doi:10.1006/APPE.2001.0398

17. Rivara F, Menestrel S Le, Prevention C on the B and PE of PVL for B, et al. *Preventing Bullying Through Science, Policy, and Practice*. National Academies Press (US); 2016. doi:10.17226/23482

18. Stigler M, Dhavan P, Van Dusen D, Arora M, Reddy KS, Perry CL. Westernization and tobacco use among young people in Delhi, India. *Soc Sci Med*. 2010;71(5):891-897. doi:10.1016/j.socscimed.2010.06.002

19. Iqbal R, Anand S, Ounpuu S, et al. Dietary patterns and the risk of acute myocardial infarction in 52 countries: Results of the INTERHEART study. *Circulation*. 2008;118(19):1929-1937. doi:10.1161/CIRCULATIONAHA.107.738716

20. Roberts HC, Denison HJ, Martin HJ, et al. A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. *Age Ageing*. 2011;40(4):423-429. doi:10.1093/ageing/afr051

21. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ*. 2007;85(9):660-667. doi:10.2471/blt.07.043497

22. Sharma AK, Metzger DL, Daymont C, Hadjiyannakis S, Rodd CJ. LMS tables for waist-circumference and waist-height ratio Z-scores in children aged 5–19 y in NHANES III: association with cardio-metabolic risks. 2015;78:Pediatric Research. http://www.nature.com/pr/journal/v78/n6/full/pr2015160a.html. Accessed July 27, 2017.

23. National High Blood Pressure Education Program Working Group on High Blood. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004;114(2 Suppl 4th Report):555-576. doi:10.1542/peds.114.2.S2.555

24. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for

reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi:10.1016/j.jclinepi.2007.11.008

25. Din-Dzietham R, Liu Y, Bielo MV, Shamsa F. High blood pressure trends in children and adolescents in national surveys, 1963 to 2002. *Circulation*. 2007;116(13):1488-1496. doi:10.1161/CIRCULATIONAHA.106.683243

26. Genovesi S, Antolini L, Gallieni M, et al. High prevalence of hypertension in normal and underweight Indian children. *J Hypertens*. 2011;29(2):217-221. doi:10.1097/HJH.0b013e3283407fe3

27. Statistics CANADA. Blood pressure of children and youth, 2012 to 2015. https://www150.statcan.gc.ca/n1/pub/82-625-x/2016001/article/14659-eng.htm. Published 2016.

28. Huntington-Moskos L, Turner-Henson A, Rice M. Tobacco exposure, weight status, and elevated blood pressure in adolescents. *J Community Health*. 2014;39(4):653-659. doi:10.1007/s10900-014-9839-5

29. Leung LCK, Sung RYT, So H-K, et al. Prevalence and risk factors for hypertension in Hong Kong Chinese adolescents: waist circumference predicts hypertension, exercise decreases risk. *Arch Dis Child*. 2011;96(9):804-809. doi:10.1136/adc.2010.202770

30. Gillis EE, Sullivan JC. Sex Differences in Hypertension: Recent Advances. *Hypertension*. 2016;68(6):1322-1327. doi:10.1161/HYPERTENSIONAHA.116.06602

31. Goel M, Pal P, Agrawal A, Ashok C. Relationship of body mass index and other life style factors with hypertension in adolescents. *Ann Pediatr Cardiol*. 2016;9(1):29. doi:10.4103/0974-2069.171393

32. Moser DC, Giuliano I de CB, Titski ACK, Gaya AR, Coelho-e-Silva MJ, Leite N. Anthropometric measures and blood pressure in school children. *J Pediatr (Rio J)*. 2013;89(3):243-249. doi:10.1016/j.jped.2012.11.006

33. Flores-Huerta S, Klünder-Klünder M, Reyes de la Cruz L, Santos JI. Increase in Body Mass Index and Waist Circumference Is Associated with High Blood Pressure in Children and Adolescents in Mexico City. *Arch Med Res*. 2009;40(3):208-215. doi:10.1016/j.arcmed.2009.02.009

34. Wang H, Necheles J, Carnethon M, et al. Adiposity measures and blood pressure in Chinese children and adolescents. *Arch Dis Child*. 2008;93(9):738-744. doi:10.1136/adc.2007.127589

35. Mirzaei M, Taylor R, Morrell S, Leeder SR. Predictors of blood pressure in a cohort of school-aged children. *Eur J Cardiovasc Prev Rehabil*. 2007;14(5):624-629. doi:10.1097/HJR.0b013e32828621c6

36. Lurbe E, Torro I, Rodríguez C, Alvarez V, Redón J. Birth weight influences blood pressure values and variability in children and adolescents. *Hypertens (Dallas,*

Tex 1979). 2001;38(3):389-393. http://www.ncbi.nlm.nih.gov/pubmed/11566910. Accessed January 17, 2017.

37. Pescatello LS, MacDonald H V., Lamberti L, Johnson BT. Exercise for Hypertension: A Prescription Update Integrating Existing Recommendations with Emerging Research. *Curr Hypertens Rep*. 2015;17(11). doi:10.1007/s11906-015-0600-y

38. Dong B, Wang Z, Arnold L, Song Y, Wang HJ, Ma J. The association between blood pressure and grip strength in adolescents: Does body mass index matter. *Hypertens Res*. 2016;39(12):919-925. doi:10.1038/hr.2016.84

39. Zhang R, Li C, Liu T, Zheng L, Li S. Handgrip Strength and Blood Pressure in Children and Adolescents: Evidence from. 2011;31(July):792-796. doi:10.1093/ajh/hpy032/4883259

40. Van kova I, Maletinska L, Behuliak M, Nagelova V, Zicha J, Kune J. Obesity-related hypertension: possible pathophysiological mechanisms. *J Endocrinol*. 2014;223(3):R63-R78. doi:10.1530/JOE-14-0368

41. Roth J V. Taller People Should Have as Their Normal a Higher Body Mass Index. *Anesthesiology*. 2018;128(2):424. doi:10.1097/ALN.0000000000001998

42. Spruill T. Chronic Psychological Stress and Hypertension. *Curr Hypertens Rep*. 2013;12(1):10-16. doi:10.1007/s11906-009-0084-8.Chronic

43. Vehaskari VM. Heritable forms of hypertension. *Pediatr Nephrol*. 2009;24(10):1929-1937. doi:10.1007/s00467-007-0537-8

44. Ehret GB. Genome-wide association studies: contribution of genomics to understanding blood pressure and essential hypertension. *Curr Hypertens Rep*. 2010;12(1):17-25. doi:10.1007/s11906-009-0086-6

Chapter 4.

Adiposity Measures and their Validity in Estimating Risk of Hypertension in South Asian Children: A Cross-Sectional Study[3]

4.1. Introduction

The prevalence of childhood obesity has been increasing globally [1]. Between 1980 and 2013 childhood overweight and obesity in developed countries increased from 17% to 24% in boys, and 16% to 23% in girls; in developing countries, meanwhile, it rose from 8% to 13% in both boys and girls within the same period [1]. Childhood obesity has adverse influence on metabolic health and blood pressure (BP), with a similar pattern to that seen in adults [2]. Compared to children with normal weight, being overweight is associated with three times the risk for hypertension (BP ≥95th percentile) [3]. In children (i.e., ≤ 18 years) with obesity the risk for hypertension is even greater at about 4–10 times the risk [4]. This is a concern as childhood hypertension typically continues into adulthood, with associated greater risk for a variety of cardio-metabolic diseases including cardiovascular diseases (CVD), stroke and renal failure [5].

South Asian ethnicity is associated with a greater risk of conventional CVD risk factors such as dyslipidemia, type 2 diabetes and abdominal obesity [6–8]. In children, studies have demonstrated increased prevalence of obesity, and concomitantly, hypertension in South Asians [9]. Specifically, South Asian children have been shown to have a unique phenotype that lends itself to higher fat at similar BMI compared to White children [10,11] placing them at greater risk for a number of diseases. This finding has important health implications as South Asians represent about 25% of the global population [12]. In Western countries such as the United Kingdom (UK), the United States (US) and Canada, South Asians represent a significant portion of visible ethnic minority groups in the population [13–15]. To reduce the potential economic impact on

[3] Fowokan AO, Punthakee Z, Waddell C, Rosin M, Morrison KM, Gupta M, Teo K, Rangarajan S, Lear SA. Adiposity measures and their validity in estimating risk of hypertension in South Asian children: a cross-sectional study. *BMJ Open*. 2019;9(2): e024087.

health care systems as well as the impact on individuals, it is crucial to address the increased prevalence of obesity with appropriate measures that are related to health risks in South Asian children.

Body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and bioelectrical impedance analysis (BIA) estimation of body fat percentage are some of the predominant measures used in research and clinical practice to assess adiposity in children as they are relatively easy and non-invasive. Several studies have assessed these adiposity measures to determine whether they are reliable indicators of obesity in the broader paediatric population [16–18]. A few studies have also explored their diagnostic accuracy in estimating metabolic risk factors such as hypertension in children [19]. However, most of these studies have been carried out in predominantly White populations. Given that differences have been observed with respect to the distribution of body fat when comparing South Asians with other ethnic groups, validating these indicators in South Asian children is important. Furthermore, it is also unclear what adiposity cut-offs might correspond to increased cardio-metabolic risk specifically in South Asian children.

This study therefore explores the association between adiposity indicators with BP and hypertension in South Asian children; and compares the accuracy of these indicators in estimating the risk of hypertension. As a secondary aim, we explore what adiposity cut-off values might be associated with risk for hypertension in this population.

4.2. Methods

4.2.1. Study Design

Participants in this study were recruited as part of the Research in International Cardiovascular Health – Lifestyles, Environments and Genetic Attributes in Children and Youth (RICH-LEGACY) study, a cross-sectional study designed to investigate CVD risk factors among South Asian children living in Canada. The study was approved by the Simon Fraser University Research Ethics Board (REB), Providence Health Care REB, and the Hamilton Integrated REB. Parents of participants provided written informed consent, while participants assented to take part in the study.

4.2.2. Recruitment

Elementary school children and high school children (n= 762) were recruited using community-based recruitment methods in two Canadian cities (Brampton, Ontario and Surrey, British Columbia) by convenience sampling between 2012 and 2016. Elementary schools with high South Asian enrolments were first identified by contacting the school boards. Once schools were identified, packages containing an invitation letter, a RICH-LEGACY study description and consent forms were sent to parent/guardians of children enrolled in the identified schools. Additionally, the study was advertised through venues used by South Asian groups including newspapers, local television stations, community centres, worship centres and festivals. Inclusion criteria included: children (in elementary or high school) having at least three grandparents of South Asian origin; being able to communicate in English; and being able to provide consent (parents) and assent (children). Research assistants fluent in Hindi and Punjabi were responsible for recruitment and data collection. The research assistants who were involved in the measurements all undertook training together through simulator sessions and were retrained if variations in measurement protocol were observed by the research coordinator. This process was repeated for a few days to ensure accuracy and consistency amongst the research assistants in the assessment of the measurements collected in this study. In addition, written materials (including consent forms) were provided in English, Punjabi, Hindi and Urdu as needed.

4.2.3. Participant Assessment and Anthropometric Characteristics

Children self-reported demographic characteristics including age and sex, while parents provided information on their own educational levels. Assessment took place in the community (i.e., at community or worship centres) depending on where children and parents were comfortable. Anthropometric characteristics including height and weight (used to calculate BMI) and WC were measured by trained researchers. WHtR was calculated using WC and height. Height was measured to the nearest 0.1cm using a right angle triangle and a calibrated wall mounted scale. Weight was measured to the nearest 0.1 kg using the Tanita Ironman Innerscan BC-554 scale with participants dressed in light clothing. Waist circumference was recorded in cm as the average of two measures taken using a non-stretching tape, against the skin after a normal expiration, halfway between the lower rib margin and the iliac crest [20]. Body fat percentage estimated by BIA was also measured using the Tanita Ironman Innerscan BC-554 fat scale. Participants were asked to stand on the Tanita scale with bare feet wearing light clothing to measure weight and estimate body fat percentage. Assessments were done at times of day convenient for children and parents irrespective of food or fluid intake. The Tanita scale has been found to yield acceptable levels of agreement when compared to dual-energy x-ray absorptiometry (DEXA) in validation studies [21, 22]. Following anthropometric assessment, BMI was transformed to z scores using the World Health Organization (WHO) 2007 growth references for young people aged 5-19 years [23]. Using WHO weight categories, normal weight was defined as BMI z-score <1, overweight as BMI z-score of 1-2 and obesity as BMI z-score >2. WC and WHtR were both transformed to z-scores using recently published values for age and sex using the Third US National Health and Nutrition Examination Survey (NHANES III – 1988-1994 and 1999-2012 cycles) [24]. The transformation to z-scores allows for standardized comparisons across children with similar or different ages and sex.

4.2.4. Blood Pressure

Blood pressure was assessed following ten minutes of seated rest in the left arm using the Omron HEM-711DLX automated BP monitor with appropriate sized cuffs. Three BP measures were taken over a 10 minute period, and the average of the three measures was recorded. Subsequently, BP was transformed to standard deviation scores and percentiles for age, sex and height according to the fourth recommendation of the US National High Blood Pressure Education Program (NHBPEP) working group report for children [5]. Systolic and diastolic hypertension were diagnosed using the NHBPEP recommendations as average systolic blood pressure or diastolic BP that is greater than or equal to the 95^{th} percentile for sex, age, and height [5].

4.2.5. Statistical Analysis

All continuous variables were examined using P-P plots and found to be normally distributed. For descriptive analysis, continuous variables were presented as means and standard deviations while categorical variables were reported as counts and percentages. Independent t-test analysis was used to assess sex differences in continuous variables, while chi-square tests were used to assess sex differences in categorical variables.

Pearson's correlation was used to examine associations between the various adiposity indicators with systolic and diastolic BP-z scores. These associations were then further adjusted for child age and sex and fathers' education in linear regression. To explore the association between adiposity indicators and systolic and diastolic hypertension, unadjusted Poisson regression was used. These models were subsequently adjusted for age, sex and fathers' education. Estimates of relative risk (RR) of systolic and diastolic hypertension were reported as incidence rate ratios (IRR) with 95% confidence intervals.

Following regression analyses, we used the area under the receiver operating characteristics (ROC) curve to compare the accuracy of the different adiposity indicators in estimating hypertension risk for both sexes. ROC analysis is a method widely known for assessing the accuracy of a diagnostic test in determining a particular health outcome. The ROC analysis is a plot of sensitivity (true positive rate) against 1 minus specificity (true negative rate) for different cut-offs for the outcome. Using the highest Youden's index (J) (a summary measure of the ROC curve) calculated as *J= Sensitivity-(1-specificity)* we determined cut-off values for the adiposity indices that optimize both the sensitivity and specificity of the adiposity indicators for identifying hypertension. Likewise, the area under the curve (AUC) was used to examine the overall strength of the adiposity indicators in estimating hypertension risk (i.e. AUC <0.7= poor; 0.7- 0.8= fair; > 0.8= good). Because the prevalence of hypertension in this sample was determined based on systolic hypertension, the ROC analysis to determine the strength and cut-offs for the different adiposity indicators was limited to just systolic hypertension. Statistical analysis was done using SPSS v. 24.0. P values <0.05 were considered statistically significant. This study was written in line with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines [25].

4.3. Results

This study included 360 boys and 402 girls (n=762) between the ages of 5.8 and 17 years (mean age of 9.5 ± 3.0 years). Mean non-transformed systolic BP was 109 ±11 mmHg while mean diastolic BP was 65 ± 8 mmHg. Significant differences were observed between South Asian boys and girls for body fat percentage (p<0.001), WC z-score (p<0.001), WHtR z-score (p=0.02), non-transformed systolic BP (p<0.001), systolic BP z-score (p=0.001), and the prevalence of systolic hypertension (p=0.01). No significant differences were observed for age, BMI z-score, diastolic BP z-score, or the prevalence of diastolic hypertension. Twelve percent of this sample was found to have systolic hypertension (Table 4.1).

Table 4.1. Socio-demographic characteristics, adiposity measures and BP values stratified by sex

	Total (n=762)	Boy (n=360)	Girl (n=402)	p value
Age (years)	9.5 ± 3.0	9.3 ± 2.8	9.7 ± 3.1	0.09
Paternal education				0.92
No formal education	5 (1%)	3 (1%)	2 (1%)	
Primary/Secondary education	247 (34%)	115 (34%)	132 (35%)	
Trade school	21 (3%)	9 (3%)	12 (3%)	
College/university	444 (62%)	209 (62%)	235 (62%)	
BMI Z score	0.48 ± 1.44	0.57 ± 1.61	0.40 ± 1.28	0.11
WC Z score	-0.06 ± 1.23	0.11 ± 0.36	-0.21 ± 1.24	<0.0001
WHtR Z score	-0.38 ± 1.24	-0.27 ± 1.27	-0.48 ± 1.21	0.02
BIA body fat %	23.6 ± 7.7	22.4 ± 8.2	24.8 ± 7.0	<0.0001
sBP Z score	0.57 ± 0.97	0.70 ± 0.99	0.46 ± 0.95	0.001
dBP Z score	0.37 ± 0.71	0.35 ± 0.68	0.39 ± 0.73	0.41
sBP (non-transformed)	109 ± 11	111 ± 12	107± 10	<0.001
dBP (non-transformed)	65 ± 8	65 ± 8	65 ± 8	0.849
Diastolic hypertension	31 (4%)	13 (4%)	18 (5%)	0.55

BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure, sBP=systolic blood pressure, dBP=diastolic blood pressure
Data are presented as mean ± standard deviation for continuous variable, counts (percentages) for categorical variables

Consistent but weak to moderate associations were observed between adiposity measures (BMI z-score, WC z-score, WHtR z-score, and body fat percentage) with systolic and diastolic BP z-scores using Pearson correlation. The strongest Pearson's coefficient for systolic BP z-score was observed for BMI z-score (r=0.430 p<0.001), while the strongest coefficient for diastolic BP z-score was observed for body fat percentage (r=0.322 p<0.001) (Table 4.2). After adjustment for covariates in linear regression analyses the significant association between all the adiposity measures with systolic and diastolic BP z-scores remained consistent (p<0.001 for all) (Table 4.3).

Table 4.2. Pearson's correlation between adiposity measures with systolic and diastolic BP z-scores.

Adiposity measures	Systolic BP z-score	Diastolic BP z-score
BMI z score	0.430, p<0.001	0.319, p<0.001
Body fat percentage	0.375, p<0.001	0.322, p<0.001
WC Z scores	0.338, p<0.001	0.210, p<0.001
WHtR Z scores	0.347, p<0.001	0.226, p<0.001

Pearson's r coefficient, and p values presented
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure

Table 4.3. Adjusted linear regression between adiposity measures with systolic and diastolic BP z-scores

Adiposity measure	Systolic BP z-score	Diastolic BP z-score
BMI z score	0.292 (0.249, 0.336), p<0.001	0.160 (0.127, 0.193), p<0.001
Body fat percentage	0.056 (0.047, 0.065), p<0.001	0.033 (0.026, 0.039), p<0.001
WC z score	0.273 (0.219, 0.326), p<0.001	0.137 (0.098, 0.177), p<0.001
WHtR z score	0.289 (0.236, 0.342), p<0.001	0.153 (0.114, 0.192), p<0.001

Model adjusted for age, sex, and fathers' education
Values presented are β (95% confidence intervals), and p values
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure

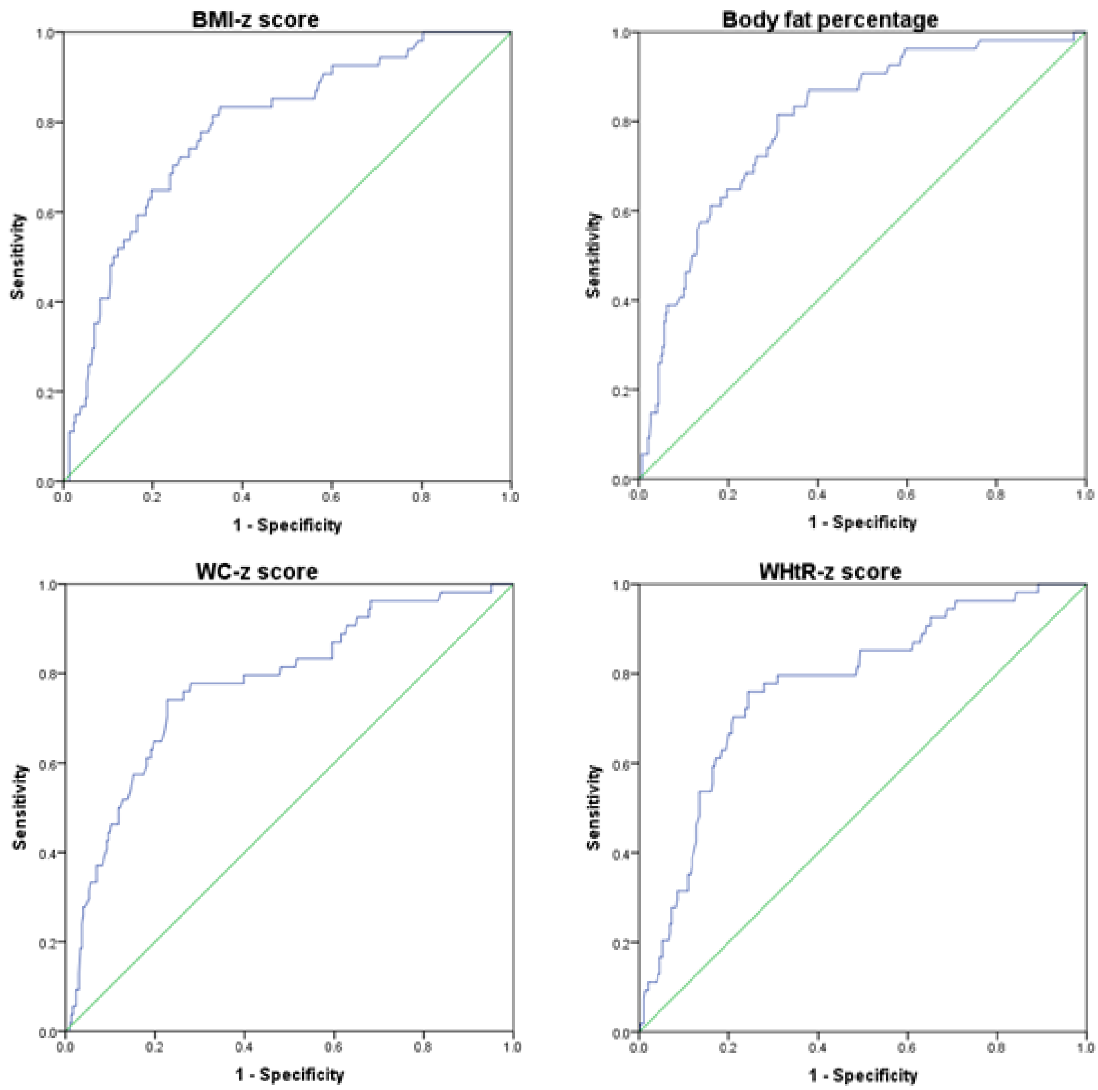
All adiposity measures had strong associations with systolic and diastolic hypertension (p<0.01 for all). The model with WC z-score had an IRR of 2.26, (95% CI= 1.82, 2.82) for systolic hypertension and an IRR of 1.83, (95% CI= 1.30, 2.60) for diastolic hypertension. Waist-to-height ratio z-score had an IRR of 2.12, (95% CI= 1.73, 2.60) for systolic hypertension and an IRR of 1.72, (95% CI= 1.24, 2.37) for diastolic hypertension. Body mass index z-score had an IRR of 1.82, (95% CI= 1.59, 2.09) for systolic hypertension and an IRR of 1.62, (95% CI = 1.28, 2.05) for diastolic hypertension. Last, the model with body fat percentage had an IRR of 1.10, (95% CI = 1.07, 1.13) for systolic hypertension, and an IRR of 1.09, (95% CI = 1.04, 1.13) for diastolic hypertension. Upon adjustment for covariates the association between the adiposity indicators with both systolic hypertension and diastolic hypertension remained (p<0.001 for all) (see Table 4.4). When compared to those with normal weight, children who were overweight or obese had an IRR of 6.19 (95% CI 3.73, 10.26, p<0.001) for developing systolic hypertension and an IRR of 4.05 (95% CI 1.86, 8.79, p<0.001) for developing diastolic hypertension. Similarly, when compared to children with WC <90^{th} percentile, South Asian children with WC above the 90^{th} percentile had an IRR of 4.41 (95% CI = 2.91, 6.68, p<0.001) for developing systolic hypertension and an IRR of 3.48 (95% CI = 1.69, 7.17, p=0.001) for developing diastolic hypertension.

Table 4.4. Incidence rate ratios for systolic and diastolic hypertension per increment in adiposity measures.

Unadjusted	**Systolic hypertension**	**Diastolic hypertension**
BMI z score	1.82 (1.59, 2.09), p<0.001	1.62 (1.28, 2.05), p<0.001
Body fat percentage	1.10 (1.07, 1.13), p<0.001	1.09 (1.04, 1.13), p<0.001
WC z score	2.26 (1.82, 2.82), p<0.001	1.83 (1.30, 2.60), p=0.001
WHtR z score	2.12 (1.73, 2.60), p<0.001	1.72 (1.24, 2.37), p=0.001
Adjusted	Systolic hypertension	Diastolic hypertension
BMI z score	1.87 (1.61, 2.18), p<0.001	1.65 (1.29, 2.11), p<0.001
Body fat percentage	1.11 (1.08, 1.14), p<0.001	1.10 (1.05, 1.15), p<0.001
WC z score	2.29 (1.82, 2.89), p<0.001	1.87 (1.33, 2.64), p<0.001
WHtR z score	2.21 (1.78, 2.74), p<0.001	1.84 (1.32, 2.55), p<0.001

Model 1= unadjusted model; Model 2= Adjusted for age, sex, and father's education
BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure
Incidence rate ratios (95% confidence intervals), and p values presented

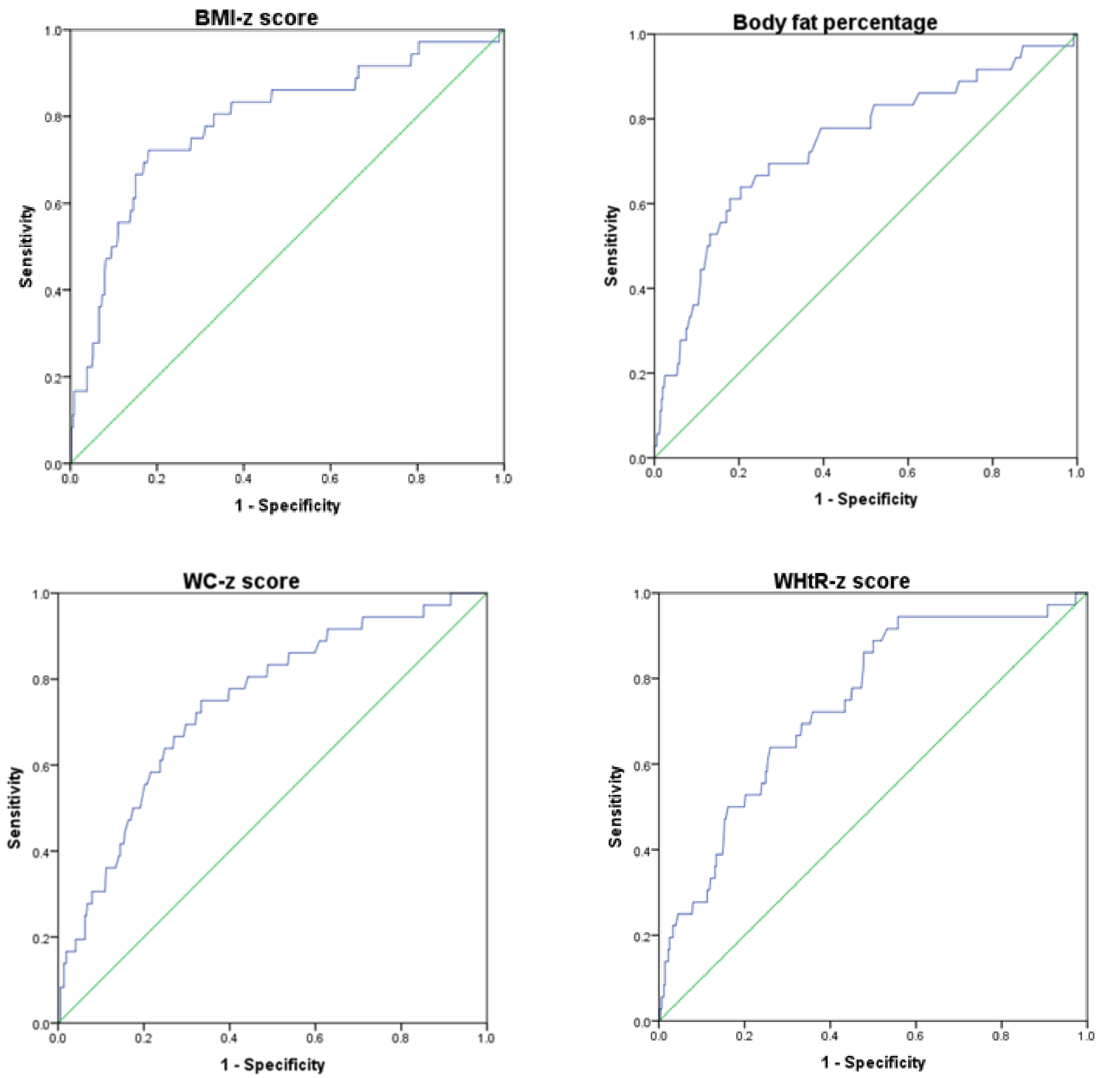
Figures 4.1 and 4.2 shows the sex-stratified AUC plots, and their values estimating the accuracy of the adiposity indicators in identifying risks for systolic hypertension. All the adiposity indicators were found to be within the range considered to be fair in their ability to estimate hypertension risk for both sexes. In boys, body fat was observed to rank high in its ability to estimate the risk of systolic hypertension (AUC= 0.80, 95% CI 0.74-0.86). The other adiposity measures were also found to be within close range of the AUC value for body fat, with BMI z-score coming next (AUC= 0.79, 95% CI 0.72, 0.85); then the WC z-score (AUC = 0.78, 95% CI 0.71, 0.85), and the WHtR z-score (AUC= 0.77, 95% CI 0.70, 0.84) (Figure 4.1). In girls, the strongest measure was found to be BMI z-score (AUC=0.79, 95% CI 0.70, 0.88), while body fat (AUC= 0.74, 95% CI 0.65, 0.83), WC z-score (AUC =0.74, 95% CI 0.66, 0.83) and WHtR (AUC =0.74 95% CI 0.66, 0.82) all had similar AUC values (Figure 4.2)



BMI z-score {AUC= 0.79 (0.72-0.85)}; Body fat percentage {AUC= 0.80 (0.74-0.86)}; WC z score {AUC= 0.78 (0.71-0.85)}; WHtR {AUC= 0.77 (0.70-0.84)}

AUC= Area under the curve, BMI = body mass index, WC=waist circumference, WHtR= waist to height ratio. P<0.001 for all

Figure 4.1. Receiver operating characteristics assessing the predictive power of adiposity indicators and systolic hypertension in boys



BMI z score {AUC= 0.79 (0.70-0.88); Body fat % {AUC= 0.74 (0.65-0.83)}; WC z score {AUC= 0.74 (0.66-0.83)}; WHtR {AUC= 0.74 (0.66-0.82)}

AUC= Area under the curve, BMI = body mass index, WC=waist circumference, WHtR= waist to height ratio

Figure 4.2. Receiver operating characteristics assessing the predictive power of adiposity indicators and systolic hypertension in girls

Sex-based cut-off values for the various adiposity indicators that were associated with adverse systolic hypertension risk, as identified using the Youden's index, and their corresponding sensitivity and specificity values are outlined in Table 4.5. The optimal cut-offs varied by sex with BMI z-score and body fat being higher in girls, and WC z-score and WHtR z-score higher in boys. The optimal cut-off for BMI z-score was 1.41 for girls and 0.92 for boys — corresponding to the 92nd and 82nd percentile respectively using the WHO 2007 reference values. For body fat, the cut-offs were 29.8% and 23.5% for girls and boys respectively. For WC z-score, the cut-offs were 0.39 for girls and 0.85 for boys, which corresponds to the 65th and 80th percentiles using the NHANES-III reference values. Last, the cut-off value for WHtR z-score for girls was 0.32, while that for boys was 0.43, corresponding to the 63rd and 67th percentiles using NHANES-III reference values.

Table 4.5. Sex-specific cut points in adiposity measures for identifying individuals with systolic hypertension.

	Optimal cut-offs	Youden's index	Sensitivity %	Specificity %
Boys				
BMI z score	0.92 (82nd percentile)[a]	0.48	83	65
Body fat %	23.5	0.51	82	69
WC z score	0.85 (80th percentile)[b]	0.51	74	77
WHtR z score	0.43 (67th percentile)[b]	0.52	76	76
Girls				
BMI z score	1.41 (92nd percentile)[a]	0.54	72	81
Body fat %	29.8	0.44	64	80
WC z score	0.39 (65th percentile)[b]	0.42	75	67
WHtR z score	0.32 (63rd percentile)[b]	0.38	64	74

BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure
[a]Percentile value is based on the World Health Organization 2007 reference values for 5-19 years old
[b]Percentile values are based on recently published LMS values using the Third National Health and Nutrition Examination Survey

4.4. Discussion

In this population of South-Asian children, we found a high prevalence of hypertension at 12%. In addition, consistent positive associations were found between adiposity indicators with systolic and diastolic BP, and systolic and diastolic hypertension. These associations remained on adjusting for socio-demographic measures. Moreover, being overweight or obese was associated with increased risk of systolic and diastolic hypertension. When sex-specific ROC curve analysis was used to validate the strength of all four adiposity measures in identifying risk of hypertension, we found them to be fair measures both in boys and girls as identified by their AUC scores. Likewise, we also estimated sex stratified optimal cut-off values for the adiposity measures that were associated with hypertension. Combined, the broad consistency observed for the adiposity measures in their association with the BP z-scores, systolic and diastolic hypertension, and their AUC values highlights their validity as fairly good measures for identifying risk of hypertension in South Asian children. The results also suggest that the adiposity measures included were similar in their ability to detect risk for hypertension.

In children, the global prevalence of childhood hypertension is not clearly known due to the lack of routine collection of BP data in children and variations in standards for defining hypertension. Studies from the US show rates that vary from 1% to 5%, but there are markedly higher rates in countries like China [26]. In Canada, prevalence of hypertension in children ages 6– 19 years was estimated at 7% [27]. In terms of ethnic comparisons, our results are consistent with results from Jafar *et al* who found 12% hypertension prevalence in South Asian children living in Pakistan [9]. This estimate was in contrast to the 5% prevalence value predicted for White children in the US [9]. It is not clear if the rates observed in our study are representative of all South-Asian children in Canada given that our sampling was restricted to volunteers in only two cities. However, the high rates obtained in this study compared to the Canadian average might be indicative of a disproportionately higher burden for hypertension in the South Asian paediatric population.

Our results showing associations between adiposity and BP and hypertension are consistent with many studies which have also explored and elaborated similar relationships [28–32]. Moreover, the consistency of the relationship between adiposity and hypertension in this study lends support to existing theories that attribute the increase in prevalence of hypertension in children partly to the concomitant increase in obesity [33]. These observed associations have important clinical implications. Blood pressure has been shown to track into adulthood [34], suggesting that problems with hypertension in childhood – if sustained and left untreated – may progress into adulthood. This in turn may result in a cascade that affects the cardiovascular and renal systems due to known links between hypertension and damage to vascular structure and function and to kidney function [35, 36]. Consequently, interventions aimed at preventing and treating obesity and hypertension should be prioritized in public health and primary care, especially for South-Asian children.

To our knowledge, this is the first study conducted with South Asian children that includes the range of adiposity measures we used. Studies carried out in other children populations have shown findings comparable to our study results. For example, in validation analysis of adiposity indicators, WHtR appeared to be a strong indicator of hypertension in both sexes, while BMI seemed to be stronger in boys, but also observed to be a good measure in estimating hypertension risk in both sexes [19]. Likewise, in children and adolescents who were overweight and obese, BIA derived body fat was comparable to BMI in estimating hypertension risk [37]. Given the South Asian obesity phenotype which lends itself to accumulation of fat in the abdominal region, and is a greater indicator of risk in adults than BMI, it was surprising to observe higher AUC values for BMI in boys and girls when compared with measures such as WC and WHtR. Longitudinal studies conducted in South Asian children are needed to confirm how fat distribution might change in South Asian children as they age.

Sex differences in the optimal cut-offs for the adiposity measures associated with hypertension were found, suggesting that the adiposity cut-offs associated with hypertension may need to be sex-specific. Moreover, when compared to reference standards from the WHO for BMI, our results suggest important considerations need to be placed in terms of differences in risk across ethnic lines. For example, the WHO 2007 definition of obesity corresponds to the 97.7th percentile, while overweight corresponds to the 84th percentile [38,39]. Based on this, the 82nd percentile observed in this study as the adiposity threshold for hypertension risk in boys would be considered normal weight using the WHO reference. It is important to note that the WHO sample included a portion of children from a South Asian country. However, it is possible that the heterogeneity in the sampling might dilute risk detection, especially in those with heightened risk predisposition such as South Asians. Similarly, the NHANES proposed the 90th percentile as the cut-off for WC in identifying risk from metabolic syndrome [40]. Our findings of WC at the 65th percentile in girls and the 80th percentile in boys again underscore the fact that South Asians may be predisposed to cardiovascular disease risk at lower fat levels. Our findings are comparable to a similar study conducted in Indian children which found that WC cut-off at the 70th percentile predicted risk of having 2 or more metabolic syndrome risk factors [41]. For WHtR in the paediatric population, studies have estimated that the ≥0.5 threshold of concern used in adults remains applicable in children [42, 43]. This threshold corresponds to WHtR at the 65th percentile in girls and the 77th percentile in boys [24]. Similar to BMI and WC, our findings show that the threshold of concern appears to be much lower in South Asians (at the 63rd percentile for girls, and the 67th for boys).

4.4.1. Strengths and Limitations

This study has two limitations. First, although we aimed to recruit a representative sample of urban South Asian children, it was not a random sample, and restricting sampling to only two Canadian cities may limit generalizability of the findings. However, given the focus of the study, a self-selection bias is unlikely. Second, this study is cross-sectional by design and as such limits to inferences about causality applies. The strength of the study lies in its large sample size of South Asian children.

4.5. Conclusion

We found BMI, BIA, WC, and WHtR to be positively associated with BP and hypertension in an urban cohort of South Asian children in Canada. Additionally, the thresholds reported for the various adiposity indicators in identifying hypertension suggest that South Asian children are at risk of hypertension at levels of excess adiposity that are less extreme than those reported in the literature for predominantly White populations. Further research is needed to replicate our findings, and to confirm findings prospectively. However, the cut-offs for the four adiposity measures provide values that would be clinically useful in estimating and addressing risk for hypertension in South Asian children. Given the ease of use, the low cost and practicality of the four adiposity measures, implementing them in primary care could be feasible and cost-effective methods for addressing the burden of hypertension in South Asian children. This would ensure that at-risk children are also identified in primary care and afforded with the appropriate preventive interventions.

4.6. References

1. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014; 384(9945): 766-781. Doi:10.1016/S0140-6736(14)60460-8

2. Sorof J, Daniels S. Obesity hypertension in children: A problem of epidemic proportions. *Hypertension*. 2002; 40(4): 441-447. Doi:10.1161/01.HYP.0000032940.33466.12

3. Rosner B, Cook N, Portman R, Daniels S, Falkner B. Blood pressure differences by ethnic group among United States children and adolescents. *Hypertens (Dallas, Tex 1979)*. 2009; 54(3): 502-508. Doi:10.1161/HYPERTENSIONAHA.109.134049

4. Koebnick C, Black MH, Wu J, et al. High Blood Pressure in Overweight and Obese Youth: Implications for Screening. *J Clin Hypertens*. 2013; 15(11): 793-805. Doi:10.1111/jch.12199

5. National High Blood Pressure Education Program Working Group on High Blood. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004; 114 :555-576. Doi:10.1542/peds.114.2.S2.555

6. Anand SS, Yusuf S, Vuksan V, et al. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE). *Lancet*. 2000; 356(9226): 279-284. Doi:10.1016/S0140-6736(00)02502-2

7. Raji A, Seely EW, Arky RA, Simonson DC. Body fat distribution and insulin resistance in healthy Asian Indians and Caucasians. *J Clin Endocrinol Metab*. 2001; 86(11): 5366-5371. Doi:10.1210/jc.86.11.5366

8. Lear SA, Humphries KH, Kohli S, Chockalingam A, Frohlich JJ, Birmingham CL. Visceral adipose tissue accumulation differs according to ethnic background: Results of the Multicultural Community Health Assessment Trial (M-CHAT). *Am J Clin Nutr*. 2007; 86(2): 353-359.

9. Jafar TH, Islam M, Poulter N, et al. Children in South Asia have higher body mass-adjusted blood pressure levels than white children in the United States: a comparative study. *Circulation*. 2005; 111(10): 1291-1297. Doi:10.1161/01.CIR.0000157699.87728.F1

10. J Eyre EL, Duncan MJ, Nevill A. South Asian Children Have Increased Body Fat in Comparison to White Children at the Same Body Mass Index. *Children*. 2017; 4(11): 102 doi:10.3390/children4110102

11. Mehta S, Mahajan D, Steinbeck KS, Bermingham MA. Relationship between measures of fatness, lipids and ethnicity in a cohort of adolescent boys. *Ann Nutr*

Metab. 2002; 46(5): 192-199. Doi:65406

12. Population Reference Bureau (2017) *2017 World Population Data Sheet*. https://assets.prb.org/pdf17/2017_World_Population.pdf Published August 2017. Accessed March 27, 2018

13. UK Office for National Statistics (2011). Ethnicity and National Identity in England and Wales. https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/ethnicity/articles/ethnicityandnationalidentityinenglandandwales/2012-12-11. Published December 11, 2012. Accessed March 27, 2018

14. Statistics Canada (2011). Immigration and Ethnocultural Diversity in Canada. National Household Survey, 2011. http://www12.statcan.gc.ca/nhs-enm/2011/as-sa/99-010-x/99-010-x2011001-eng.cfm. Published September 15, 2016. Accessed March 27, 2018

15. Hoeffel EM, Rastogi S, Kim MO, Shahid H. The Asian Population: 2010. 2010 Census Briefs. *Washington, DC: US Census Bureau* 2012; 1-23.

16. Eisenmann JC, Heelan KA, Welk GJ. Assessing Body Composition among 3- to 8-Year-Old Children: Anthropometry, BIA, and DXA. *Obes Res*. 2004; 12(10): 1633-1640. Doi:10.1038/oby.2004.203

17. Dencker M, Thorsson O, Lind?n C, Wollmer P, Andersen LB, Karlsson MK. BMI and objectively measured body fat and body fat distribution in prepubertal children. *Clin Physiol Funct Imaging*. 2007; 27(1): 12-16. Doi:10.1111/j.1475-097X.2007.00709.x

18. Sun Q, Van Dam RM, Spiegelman D, Heymsfield SB, Willett WC, Hu FB. Practice of Epidemiology Comparison of Dual-Energy X-Ray Absorptiometric and Anthropometric Measures of Adiposity in Relation to Adiposity-Related Biologic Factors. *Am J Epidemiol*. 2010; 172(12). Doi:10.1093/aje/kwq306

19. Papalia T, Greco R, Lofaro D, Mollica A, Roberti R, Bonofiglio R. Anthropometric measures can better predict high blood pressure in adolescents. *J Nephrol*. 2013;26(5):899-905. Doi:10.5301/jn.5000235

20. WHO (2011) Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation, Geneva, 8–11 December 2008. Technical report, World Health Organization

21. Barreira T V, Staiano AE, Katzmarzyk PT. Validity assessment of a portable bioimpedance scale to estimate body fat percentage in white and African-American children and adolescents. *Pediatr Obes*. 2013; 8(2): e29-32. Doi:10.1111/j.2047-6310.2012.00122.x

22. Kabiri LS, Hernandez DC, Mitchell K. Reliability, Validity, and Diagnostic Value of a Pediatric Bioelectrical Impedance Analysis Scale. *Child Obes*. 2015; 11(5): 650-655. Doi:10.1089/chi.2014.0156

23. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ*. 2007; 85(9): 660-667. Doi:10.2471/blt.07.043497

24. Sharma AK, Metzger DL, Daymont C, Hadjiyannakis S, Rodd CJ. LMS tables for waist-circumference and waist-height ratio Z-scores in children aged 5–19 y in NHANES III: association with cardio-metabolic risks. *Pediatric Research*. 2015; 78: 723–729. Doi:10.1038/pr.2015.160

25. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

26. Rao G. Diagnosis, Epidemiology, and Management of Hypertension in Children. *Pediatrics*. 2016; 138(2): e20153616. Doi:10.1542/peds.2015-3616

27. Statistics CANADA. Blood pressure of children and youth, 2012 to 2015. https://www150.statcan.gc.ca/n1/pub/82-625-x/2016001/article/14659-eng.htm. Published 2016.

28. Jago R, Mendoza JA, Chen T, Baranowski T. Longitudinal associations between BMI, waist circumference, and cardiometabolic risk in US youth: Monitoring implications. *Obesity*. 2013; 21(3): E271-E279. Doi:10.1002/oby.20080

29. Mirzaei M, Taylor R, Morrell S, Leeder SR. Predictors of blood pressure in a cohort of school-aged children. *Eur J Cardiovasc Prev Rehabil*. 2007; 14(5): 624-629. Doi:10.1097/HJR.0b013e32828621c6

30. Brion MA, Ness AR, Davey Smith G, Leary SD. Association between body composition and blood pressure in a contemporary cohort of 9-year-old children. *J Hum Hypertens*. 2007; 21(4): 283-290. Doi:10.1038/sj.jhh.1002152

31. de Onis M, Martínez-Costa C, Núñez F, Nguefack-Tsague G, Montal A, Brines J. Association between WHO cut-offs for childhood overweight and obesity and cardiometabolic risk. *Public Health Nutr*. 2013; 16(4): 625-630. Doi:10.1017/S1368980012004776

32. Kim NY, Hong YM, Jung JW, Kim NS, Noh C Il, Song Y-H. The relationships of body mass index, waist-to-height ratio, and body fat percentage with blood pressure and its hemodynamic determinants in Korean adolescents: a school-based study. *Korean J Pediatr*. 2013; 56(12): 526-533. Doi:10.3345/kjp.2013.56.12.526

33. Tu W, Eckert GJ, DiMeglio LA, Yu Z, Jung J, Pratt JH. Intensified effect of adiposity on blood pressure in overweight and obese children. *Hypertension*. 2011; 58(5): 818-824. Doi:10.1161/HYPERTENSIONAHA.111.175695

34. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: A systematic review and meta-regression analysis. *Circulation*. 2008; 117(25): 3171-3180. Doi:10.1161/CIRCULATIONAHA.107.730366

35. Urbina EM. Abnormalities of vascular structure and function in pediatric hypertension. *Pediatr Nephrol*. 2016; 31(7): 1061-1070. Doi:10.1007/s00467-015-3188-1

36. Lubrano R, Travasso E, Raggi C, Guido G, Masciangelo R, Elli M. Blood pressure load, proteinuria and renal function in pre-hypertensive children. *Pediatr Nephrol*. 2009; 24(4): 823-831. Doi:10.1007/s00467-008-1077-6

37. Bohn B, Müller MJ, Simic-Schleicher G, et al. BMI or BIA: Is Body Mass Index or Body Fat Mass a Better Predictor of Cardiovascular Risk in Overweight or Obese Children and Adolescents? A German/Austrian/Swiss Multicenter APV Analysis of 3,327 Children and Adolescents. *Obes Facts*. 2015; 8(2): 156-165. Doi:10.1159/000381227

38. de Onis M, Garza C, Onyango AW et al. WHO Child Growth Standards. *Acta Paediatr*. 2006; 95(450): 106. Doi:10.1037/e569412006-008

39. Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes*. 2010; 5: 265-273. Doi:10.3109/17477160903268282

40. National Heart, Lung and Blood Institute. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: summary report. *Pediatrics*. 2011; 128 Suppl: S213-56. Doi:10.1542/peds.2009-2107C

41. Khadilkar A, Ekbote V, Chiplonkar S, et al. Waist circumference percentiles in 2-18 year old indian children. *J Pediatr*. 2014; 164(6): 1358-1362.e2. doi:10.1016/j.jpeds.2014.02.018

42. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message – “keep your waist circumference to less than half your height.” *Int J Obes*. 2006; 30(6): 988-992. Doi:10.1038/sj.ijo.0803226

43. Khoury M, Manlhiot C, McCrindle BW. Role of the Waist/Height Ratio in the Cardiometabolic Risk Assessment of Children Classified by Body Mass Index. *J Am Coll Cardiol*. 2013; 62(8): 742-751. Doi:10.1016/j.jacc.2013.01.026

Chapter 5.

Exploring Knowledge and Perspectives of South Asian Children and their Parents Regarding Healthy Cardiovascular Behaviours: A Qualitative Analysis

5.1. Introduction

South Asian ethnicity refers to individuals who have ethnic roots in countries that collectively make up the Indian subcontinent. These countries include Bangladesh, India, Nepal, Sri-Lanka and Pakistan. The comparatively higher burden of risk factors for cardiovascular disease (CVD) in South Asians adults has been well documented [1]. Similarly, South Asian children have a higher prevalence of hypertension and higher body fat relative to White children [2,3]. South Asian children and adults also tend to have lower levels of physical activity, higher consumption of dietary fat and a limited knowledge of CVD risk and health practices [4,5], suggesting that significant potential for CVD risk reduction in South Asians might lie in targeting behaviour.

Lifestyle interventions aimed at addressing the burden of CVD in South Asians in primary care settings have demonstrated modest promise in weight, blood pressure and cholesterol reduction [6]. However, it remains unclear how effective these interventions are in altering behaviour in the long-term. Additionally, qualitative studies conducted in adults have shown that South Asians experience significant barriers to behaviour change [7]. For example, one study in the United Kingdom (UK) found South Asians to report cultural barriers to physical activity uptake and dietary change [8]. Comments such as, *“I can't leave our food, this is what I have been eating since I was born and is what I will eat until I die”* and *“I would like to swim, but as yet have not found a place where I will be allowed to swim with my karpaan [religious dagger]*”, were used to describe barriers to dietary change and physical activity uptake [8], respectively.

A key aspect in creating effective health education and behaviour change messages is through the understanding of cultural or individual beliefs and perspectives around health-related behaviours to enable the tailoring of more proactive and effective interventions [9]. The few studies that have sought to understand cultural barriers to behaviour change in the South Asian population have mostly focused on the individualized perspective of children and adults alone without exploring the combined and interactive family perspectives of children and their parents. Given that a disproportionate burden of CVD related outcomes have also been found in South Asian children [2,10,11], and that CVD-related behaviours in children such as diet and physical activity are influenced by parental behaviours and a range of other factors, understanding this combined perspective seems vital. The present study therefore focuses on understanding: 1) knowledge about CVD risk in both South Asian children and parents; and 2) attitudes towards physical activity and diet in both the parents and children, including potential cultural influences.

5.2. Theoretical Framework

The theoretical framework underpinning this research study is adopted from Resnicow et al.[12]. This framework underscores the need for cultural sensitivity in the development of health promotion and intervention programs – by taking into consideration how the intersection between behaviour, environment and culture affects attitudes and beliefs about health-related factors for a given population. Resnicow et al. define cultural sensitivity using two dimensions: surface and deep structures. Surface structures delineate the need for connecting health promotion messages with identifiable characteristics such as dietary or physical activity preferences of the target audience with the aim of improving uptake [12]. Deep structures, in contrast, refer to the integration of socio-cultural, environmental and psychological forces that influence the targeted behaviour of the specific population being studied [12]. An application of cultural sensitivity at the deep structure level is exemplified in understanding how individual culture, religion or the societal environment influences behaviour for South Asian children and their parents. Understanding what role culture and related factors play in influencing these health behaviours is essential, furthermore, in informing the design of effective health promotion and other intervention programs. We also utilized this framework in the development of the interview guide to explore the role of the societal, cultural and religious environments in health behaviours in children and their parents. The framework was useful during data coding in helping with the organization of codes and in making useful conceptual delineations of codes into themes that touched on the influences of both surface and deep structures on child and parent behaviours.

5.3. Methods

5.3.1. Study Design

We recruited child (ages 10– 18 years) and parent dyads by contacting individuals who had previously participated in the Research in International Cardiovascular Health – Lifestyles, Environments and Genetic Attributes in Children and Youth (RICH-LEGACY) study. The RICH-LEGACY study was a cross-sectional investigation of risk factors for CVD among South Asian children in Canada. During recruitment, participants were invited to consent to be contacted for a future follow-up qualitative study. This qualitative study provides complementary insights [13] to previous RICH-LEGACY quantitative findings [14] by illuminating the socio-cultural influences on South Asian child and parent behaviours.

In addition to recruiting individuals from the RICH-LEGACY study, a small number of participants (both children and their parents) who did not take part in the RICH-LEGACY study were recruited. These children were recruited by a South Asian research assistant who had established rapport with these community members. This was done to ensure that diverse viewpoints were obtained, including from participants who did not contribute to the RICH-LEGACY study findings. We utilized purposive sampling to recruit children from a range of age groups and BMI levels and from both sexes to ensure representation across the demographic spectrum. To ensure that non-English-speaking parents were included, interviews were available in Punjabi. We chose to recruit children over 10 years old because that threshold provided us with children who were knowledgeable, cognitively aware and competent in communication – thereby avoiding issues like relying on parents for responses, which have been reported in children of younger ages [15]. Research Ethics Boards (REBs) at Simon Fraser University and Providence Health Care approved the study. Parents provided written informed consent, while children assented to take part in the study.

5.3.2. Data Collection

In-depth interviews were conducted with South Asian children and their parents over a four-month period in 2018 using a semi-structured interview guide that was developed based on similar qualitative studies in South Asian child and adult populations. To avoid parental influences on child responses, we interviewed children and parents separately. The interview guide explored questions related to physical activity and diet, and relevant socio-cultural factors including the influences of schools and social and cultural environments. The interviews were conducted until data saturation was attained. Data analysis was ongoing and iterative throughout the interview process, informing the point at which data saturation was achieved. Participants were interviewed over the phone (n=9 child-and-parent dyads) or in-person (n=4 child-and-parent dyads) based on participant preference. Two interviews were conducted in Punjabi and the remainder in English. Interviews with dyads lasted on average between 25– 40 minutes. The first author (AF), who has a background in health sciences and an awareness of potential issues in conducting research with children, conducted nine interviews. The research assistant, also trained on potential issues in conducting research with children, conducted three interviews, including the interviews in Punjabi. One interview was conducted jointly. Translation from Punjabi to English was conducted by the research assistant.

5.3.3. Data Analysis

Interviews were digitally recorded and transcribed verbatim. For interviews conducted in Punjabi, the interviews were translated and transcribed into English by a research assistant fluent in both languages. Following this, the interview transcripts were reviewed several times and the data were coded. We utilized both inductive and deductive coding to then undertake thematic analysis of the data [16]. This was done by firstly generating draft codebooks to guide the coding process using existing literature evidence. The codebooks were then refined as the coding process went on, and in cases where portions of the interview transcripts were not captured by existing codes, new codes were developed. Upon completion of the first round of coding, a second round of coding was conducted to aggregate similar codes, providing insight into identifiable themes emerging from the data. The coding process was done separately for the child and parent interviews. However, child codes were constantly compared to parent codes to highlight similarities and differences in themes for both groups. Coding was completed by two independent researchers (AF and KV – a research coordinator with extensive coding experience) and inter-rater reliability between the two was calculated and found to be good. Disagreements in the coding process were resolved by discussion until consensus was reached. To allow for broad representativeness in participant views outliers – or cases which contradicted the ideas emerging from the data – were identified and incorporated in the analysis. Data analysis was aided by NVivo 14 (QSR international, Australia). Interview guide is available in appendix a.2.

5.4. Results

Four key themes emerged from the data analysis: 1) knowledge about CVD (including its management and prevention); 2) attitudes and knowledge about healthy diets; 3) attitudes and knowledge about physical activity; and 4) other factors. Below we summarize these themes in more detail, together with illustrative quotes from participants, edited for clarity. Table 5.1 provides an overview of the participant sociodemographic characteristics, while Table 5.2 summarizes the main themes identified in the study.

Table 5.1. Sociodemographic and anthropometric distribution of child-parent dyad

Characteristic		Child-parent dyads (n=13)
Child age		14.1 ± 2.2
Child sex		
	Female	5 (38%)
	Male	8 (62%)
Children's BMI categories		
	Normal weight	6 (50%)
	Overweight	3 (25%)
	Obese	3 (25%)
Parent's sex		
	Female	8 (62%)
	Male	5 (38%)
Parent's highest education		
	No formal education	0
	Primary/Secondary school	4 (31%)
	Trade school	4 (31%)
	College/University	5 (39%)

BMI= Body Mass Index

Table 5.2. Key themes emerging from the data analysis

Common themes for both child and parent interviews	
Knowledge about cardiovascular disease—including the role of diet, physical activity and broader holistic factors in reducing risk.	
Physical activity preferences, dislikes, barriers and motivators	
South Asian diet	
General health literacy	
Barriers and motivators to healthy eating	
Themes unique to parents	**Themes unique to children**
Cultural or religious influences on health behaviour	School, peer and social media influences on health behaviour

5.4.1. Knowledge about Cardiovascular Disease

Children

Most child participants were aware of the beneficial effects of a healthy lifestyle, highlighting the combined role of diet and physical activity in addressing the higher risk of CVD in South Asians. Some also suggested the role of broader wellbeing in addressing CVD risk.

> "I think exercising and eating healthy are the best ways to reducing heart disease in both children and adults." (RL6: Male, age 14)

> "Not eating junk foods and eating a lot of healthy foods like green stuff—vegetables, fruits and lentils." (RL9: Male, age 11)

> "Don't be stressed a lot. Being positive also helps in keeping your heart healthy." (RL11: Female, age 13)

Parents

Similar to the children, most parents interviewed in this study were aware of the higher CVD risk in the South Asian population, noting the role of lifestyle factors in increased risk. When asked what needed to be done to address this risk, most parents highlighted the importance of physical activity and healthy diets. However, some also noted the influence of changes in geographical location on CVD risk-related behaviour in South Asians, suggesting that acculturation to Canada might be less favourable to the adoption of physical activity.

> "South Asians eat more oily food and lack a lot in physical activity, and this increases their risk of heart disease."(RL3)

> "South Asian foods are not very healthy like rich in vegetables, rather we eat foods that might be high in sugar like rice, sugary foods and foods processed from wheat. In Asia where we come from we eat a lot of these things but we do physical activity to offset their impact. Here, people sit for long hours and there is less activity, so they have to eat less of the unhealthy things and prioritize healthy food." (RL9)

As well, some parents highlighted the importance of broader approaches to addressing CVD risk in South Asians. These included relaxation techniques and a focus on prevention for addressing the burden of CVD in South Asians.

> "Meditation and breathing exercises are also important for cardiovascular health."(RL10)

> "Limit unhealthy behavior. I think the focus has to be more on wellness and prevention based education more" (RL2)

5.4.2. Attitude Towards Diet

Taking into account the specific role that diet plays in the development and progression of CVD risk factors and the strong cultural component attached to diet, we asked participants about their attitudes towards diet. This included their knowledge about healthy foods, the South Asian diet and barriers to healthy eating.

Children

Given the higher CVD risk in South Asians, which has also been observed in children, we asked children about their thoughts regarding what was responsible for the increased CVD risk in South Asians. All the children interviewed documented the contributory role of aspects of the South Asian diet.

> "Well, it can be due to what we are putting in our food, for instance a lot of oil." (RL5: Male, age 13)

> "Probably because we eat a lot of bad food." (RL8: Female, age 16)

When asked to define what a healthy diet was, children provided conceptual and technical definitions of a healthy diet. This included details such as noting the Canada's

Food Guide and the major food groups it specifies and their servings, including how these servings might vary depending on metabolic needs.

> "The healthy diet is what we learn about Canada's Food Guide. You need 5-12 servings daily and only 2-3 of meat and alternatives, 5-10 of fruits and vegetables, but these serving size depend on the person and how active they are." (RL10: Male, age 13)

> "Having all the major food groups, you know, eating all the food groups each day."(RL13: Female, age 14)

> "The right servings of all the food types—fruit and veggies, dairy product and meat product-- that is contained in the food guide." (RL2: Female, age 12)

Despite the nutritional awareness that children showed, there was a mixed response when they were asked to assess the quality of the diet that they consumed. Children also identified a range of influences on dietary behaviour including the influence of peers.

> "I think it is (healthy) but I think I can make it better. I eat a lot of home cooked meals and rarely eat outside the house. My daily calories are usually about 2000 and I drink a lot of water and eat lots of proteins but I think limiting the salty foods I eat and fried foods can make my diet better." (RL7: Male, age 17)

> "I don't think my diet is healthy. I don't eat a balanced diet, I always just eat when I am hungry. When I do eat, I do not eat a whole lot of healthy food. I want to eat healthy, be healthy and eat the good stuff but sometimes I just want to be lazy." (RL1: Female, age 10)

> "I think generally speaking the food I eat at home is healthy. My parents make sure that we eat good healthy foods at home. When I am out with friends though, I sometimes feel pressured to eat junk foods."(RL6: Male, age 14)

For children who self-assessed their diet as unhealthy, we asked them why, given their understanding of the importance of healthy foods, they still ate unhealthy foods. Most children noted the appealing taste and flavour of the unhealthy foods as the biggest barrier to healthy eating.

> "The thing that stops me from eating healthy is the fact that the foods I eat taste better and have more flavour and texture than the healthy foods that are given to me." (RL8: Female, age 16)

> "The taste of all of the other amazing foods stops me from eating healthy." (RL3: Male, age 15)

For children who self-assessed their diet as healthy, we asked them about motivations for dietary choices. A range of motivations for healthy eating were highlighted, including not wanting to be bullied for their weight. One child with diabetes also mentioned the presence of the health condition as a motivator for maintaining healthy dietary practices.

> "I think at school, like there are a lot of people that do not look healthy, you know at school sometimes you get bullied if you're fat and I do not want to be that person to get bullied, so I keep eating healthy. I do not want to gain a lot of weight." (RL13: Female, age 14)

> "You know people judge you on the way you look so I feel like that will motivate someone. Diabetes is also a strong motivator, it reminds me to cut down excess sugar from my diet." (RL4: Male, age 16)

Parents

Most parents demonstrated good general nutritional awareness when asked to explain what healthy eating meant, referring to Canada's Food Guide in some cases as the standard to follow. Parents also mentioned the need for dietary diversity (i.e., including a variety of foods) and the importance of checking food labels.

> "Enough fruits and vegetables, fair amount of proteins in it, limiting sugary things, you know, Canada Food Guide kind of recommendation." (RL2)

> "Eating healthy means eating protein, fiber, a little bit of everything." (RL1)

> "Yes, we always read the labels. For instance, bread should have 5% fiber, you want to know the nutrition values for the food you buy, and also the amount of salt/sodium present." (RL5)

There were mixed responses from parents about the healthiness of the South Asian diet. Some parents highlighted the potential issues with the traditional diet, especially those related to its high saturated fat content and the frequent use of ghee (a type of clarified butter used by South Asians) in cooking. A few parents, however, highlighted important variations in the South Asian diet and how that might vary based on the particular South Asian country one originated from, and specific dietary restrictions practised by the family, including being vegetarian. Some of the parents wrongly included spices as components of the diet that might be unhealthy.

> "I think that varies from family to family. Our version of the South Asian diet is healthy. We are vegetarian so we only eat lots of vegetables, low fat milk, whole wheat foods and we try to use less oil and when we do we use low fat butter and reduce lots of frying." (RL7)

> "The traditional South Asian diet is healthy because you are not eating a lot of fried food. We use less oil than Indian and Pakistani food and it's not too much spicy, and use a lot of vegetables." (RL11)

> "The South Asian diet is not as bad as people say it is. Yes, if you put too much butter or fry a lot and a lot of the spices then that is not good for you. I think it mostly depends on your individual version of what the South Asian diet is, how you cook the food." (RL6)

One parent suggested that eating ghee might not be as bad as it is portrayed speculating its apparent health benefits. Another parent acknowledged the challenges with behaviour change as it relates to food for South Asians

> "Do you know everybody is eating the ghee right now and the turmeric, putting it in their coffee and tea. It is good for you now, it is good for your health. Everything is good for you if you stay in your

> limit, if you go above the limit then it becomes bad. Your body needs fat, if you do not have it, how are you going to survive?" (RL12)

.

> "I will say South Asians really like sweets and they also do not want to give up their butter…I can't give up my butter either." (RL1)

One participant highlighted the role of family structures and the challenges it poses to influencing health behaviour. In particular, it appears that family dynamics might exert influences on dietary related behaviour, as older family members might not be as amenable to change as younger family members; so their presence in households might make it harder to make healthier changes to meals.

> "So, if it is a typical South Asian or Indian family with older generations living in the household then I think the food might need some work because there will probably be more fats, oils and fried foods. But if there is no grandparents around and the family has been here for a while, and they are aware, then I think it is good…Because it is very hard to change the habits of older people" (RL2)

Health reasons appeared to be the strongest motivator for healthy eating. In particular, families with a history of CVD risk appeared to be more amenable to dietary changes.

> "I will say after the doctor diagnosed me with high cholesterol. That was a few years ago and I realized I do not want to suffer that again because it could lead to a heart attack and then I started changing after that. We have been pretty much eating healthy after our kids. When we first got married, we both were working seven days a week and didn't care about food but after we had our kids we decided to be more careful to make sure they eat healthy food." (RL13)

> "My biggest motivator for being health conscious especially with what I eat and how active I am is because my parents had issues with their health—high blood pressure problems and other complications"(RL6)

> "My son is a diabetic that is why the dietitian told me what kind of food to cook…he said, brown flour is healthy, brown rice is healthy, vegetables is healthy" (RL4)

5.4.3. Attitudes Towards Physical Activity

Children

Children demonstrated a good level of knowledge about the importance of physical activity, highlighting its physical and mental health benefits. Its impact on improving focus in school was also mentioned.

> "I think it is important because it helps you develop muscle and make you stronger. I think overall you are more athletic and healthy than someone who doesn't exercise." (RL 12: Male, age 14)

> "Yes, physically activity is important. Besides the fact that it can help prevent diseases and keep people fit, for me, I feel better mentally every time I take part in physical activity like playing basketball with my friends…it keeps my mind awake." (RL6: Male, age 14)

> "I find that it helps me a lot to focus during the school as well as calming me down." (RL13: Female, age 14)

The school environment was frequently highlighted as one of the biggest influences on children's physical activity behaviour. A few students also commented on the positive influence of peers on physical activity uptake.

> "I am active at school because we have PE almost every day and sometimes in the middle of class the teachers ask us to get up and stretch." (RL11: Female, age 13)

> "I am active at school because I am more active in the morning and I am at school in the mornings". (RL1; Female, age 10)

> "I like to play sports, mostly basketball and it is more fun to play with friends than play alone. I think friends motivate you to take part in physically active because when I am by myself at home I mostly watch TV." (RL10: Male, age 13)

Children cited a range of barriers that affected their levels of physical activity. These barriers involved the excessive use of technological media such as TV, video games and mobile phones.

> "Sometimes when I am playing video games, I do not want to go outside to play with my friends." (RL9: Male, age 11)

> "I will much rather play my video games at home than to go ride a bike."(RL2: Female, age 12)

> "My phone definitely stops me from being physically active because once I start to do something on my phone, I don't realize how long I have been doing that one thing." (RL8: Female, age 16)

Parents

Previous studies have reported religious and cultural barriers to physical activity uptake, such as the inability to wear parts of the religious attire in conventional recreational spaces such as swimming pools. So we asked parents about the influence of culture and religion on their choice of physical activity.

> "For me, I do not believe religion and culture play a role in the type of activity I engage in. Would I participate in something like Bhangra (a traditional South Asian dance) if I had the opportunity? Yes, but that's because dancing is my hobby and I like to get involved in something that I like to do and if it gets me active then count me in." (RL6)

> "I think culture is a huge part of everyone's life but I do not think it should impact your need to be healthy. Exercise keeps you healthy that is why I participate in it regularly." (RL7)

Health reasons were given as motivations for participation in physical activity. One parent also highlighted the communal camaraderie received from participating in physical activity with groups of other women and how that might positively influence the uptake of physical activity.

"Your health proves important to an individual participating in physical activity. For instance, I have high blood pressure problems, however I have noticed that when I go walking, it helps with my blood pressure so this is an activity that I do more often." (RL3)

"Few years ago I had high cholesterol and my doctor recommended physical activity." (RL13)

"Groups with other women, help me be physically active. Even other people when I walk around the neighbourhood, it allows you to do more than just exercising and you can catch up with friends." (RL10)

However, most parents highlighted that they were less likely to participate in rigorous activity such as gym exercises and organized sports. This was mostly due to the physical demanding nature of these activities, but some parents also found them unenjoyable.

"Anything that involves too much weight lifting I wouldn't do. I also do not run because of my knee so I go for long slow walks every day." (RL9)

"I used to do the gym before but that wasn't the type for me and I did not enjoy it at all." (RL12)

Parents also documented a range of barriers to the uptake of physical activity. The most commonly highlighted barriers were lack of time and the presence of certain health conditions which might impede the uptake of physical activity, such as musculoskeletal injuries.

"Time is the main factor. Just busy with work and the kids stops me being physically active." (RL11)

"The biggest barrier for me is because I have shoulder pain. Another thing is my feet swell up, and get tired and eventually hurt."(RL5)

5.4.4. Other Factors

In addition to the themes already discussed, both children and parents highlighted other salient factors throughout the interviews. These factors related to a range of influences which could positively or negatively affect CVD-related behaviours. For children, these factors included technological and social influences, while for parents these factors included the positive impact of health practitioners on behaviour.

Children

The connections between social media, societal influences and advertising appeared frequently as important factors in terms of their negative effects on behaviour change. Specifically, some children raised concerns regarding the influx of advertisements on social media platforms that portrayed unhealthy habits as fashionable.

> "I think sometimes social media has a negative effect on behaviour. For example, smoking is presented on social media as a good thing and that can affect children's habits, same for junk food." (RL2: Female, age 12)

> "I think we need to put a stop that kind of stuff—the adverts on social media. Maybe something like if you put that stuff up on social media you get banned or not allowed to use social media anymore." (RL9: Male, age 11)

However, some children also highlighted the potential of social media in promoting healthy behaviour. In particular, they highlighted the impact of influential individuals on social media who utilized their platforms to promote healthy behaviours.

> "Yes, I think social media influences a lot of young people. I follow a lot of people who body build and watching their videos motivates me to work out more." (RL7: Male, age 17)

> "I feel like more people look at social media and want to be like what they see. So, if more celebs posted on what are some good healthy recipes a lot of people will follow that I think."(RL4: Male, age 16)

> "Sometimes it can help motivate you. Like, I like LeBron James and if I saw him eat healthy I might do the same too because I think he is successful at what he does and I want to be successful like him." (RL12: Male, age 14)

Parents

Some participants highlighted the positive role played by doctors and researchers in improving personal health behaviours. One participant also provided suggestions regarding targeted health promotion to South Asians to improve behaviours.

> "Most of our food choices are based off recommendations from a dietitian (researcher). I saw them when I was a PhD student at SFU and they gave us information about good dietary habits." (RL9)

> "…the family doctors should mention things like exercise and eating healthy to people a little bit more maybe and give them a hard time. I always used to be scared when I go to my family doctor because she is so strict (laughs). She tells me that I have to watch out and I always listen to her." (RL13)

> "We can have the workshops around, people (health specialists) should come to the gudwarra (our temples), they can give brochures to people there and educate them about diet and how to cook healthy foods. I think that is a really good start, especially for the elderly, having it in their language also, discussing what food is good for you and what is not good for you."(RL12)

5.5. Discussion

We sought to examine knowledge of CVD and the range of influences on CVD-related behaviour in a sample of South Asian children and their parents. Four themes were identified: knowledge about heart disease, attitudes towards diet, attitudes towards physical activity, and other factors. For knowledge about heart disease, both children and parents noted the influence of behavioural factors and in some cases, broader holistic factors in preventing CVD. For the other themes, we documented the range of influences on health behaviours for both children and their parents, highlighting potential barriers and motivators. Understanding children's perspectives in addition to the parents' is important as it helps highlight salient factors that should be considered when potentially designing interventions aimed at South Asian children.

As revealed by the interviews with South Asian children and parents, there appeared to be good level of awareness about factors that might increase CVD risk. Most participants attributed the high CVD risk in the South Asian population to poor diet and inadequate physical activity. Yet it appeared the knowledge about CVD risk did not necessarily translate into behaviour change as evidenced by the number of children and parents who reported that their diets were unhealthy. This apparent dissonance between knowledge and action when it comes to healthy eating has also been observed in Hispanic-American child and parent dyads [17] and in White Canadian children [18].

Most participants were aware of the public perception that the South Asian diet was unhealthy. Yet it was clear from the interviews the South Asian diet was diverse. Parents highlighted differences in their definition of the South Asian diet depending on their country of origin. Additionally, some parents underscored how the practice of vegetarianism improved their version of the South Asian diet. It also appeared that family dynamics played an important role in the way South Asians prepared meals. Certain families were knowledgeable and aware about the dietary implications of unhealthy eating practices and were more amenable to lifestyle changes for a range of health reasons. But in certain cases, dietary changes appeared to be more challenging, for example, owing to the presence of older and more traditional family members who were particular about the cultural integrity of the foods – often characterized by the use of considerable oil and frying. Given that parental practices have a profound influence on diet and physical activity for children, particularly those who are younger [19], understanding motivations for behaviour change and the family dynamics seem important to consider when trying to promote healthy dietary habits in this population.

Perhaps noteworthy are the thematic differences observed between child and parent behavioural influences. Other than parental influences on food consumed at home, there appeared to be marked differences in the range of behavioural influences for children and parents. The impact of culture, especially as it relates to diet, was less salient for children. More so, children’s diet and physical activity were influenced by their social environment (peers, school and social media). In contrast, for parents, cultural factors and health reasons were the most important influences. These findings could possibly be a result of differences in acculturation whereby children of immigrant parents become immersed into the host culture more quickly than their parents [20]. It is also possible that the observed differences might be generational, without links to culture, perhaps owing to changing social norms. Similarly, in a multi-ethnic qualitative study, Tiedge *et al.* found that generational differences between adolescents and adults were greater than the differences observed among peers of different ethnic groups [21]. Consequently, these gaps in behavioural influences suggest that potential interventions aimed at promoting lifestyle changes in South Asian populations must be different for children compared to their parents.

We sought to explore culturally-relevant themes relating to diet and physical activity in both children and parents. Cultural factors appeared to be more intrinsic to the parents' dietary decision-making processes than for children. For children, dietary patterns were mostly influenced by taste, social interactions and "junk food" advertisements. For some children, even when they showed motivation to eat in a more healthy way, pressure from friends who ate "junk foods" seemed to influence their convictions. In other cases, certain children attributed their "junk food" consumption to the appealing taste of these foods and social media advertisements or celebrities who made "junk food" consumption look fashionable. These findings raise several considerations regarding protecting children from the sometimes pernicious effects of social advertising. Furthermore, as children appeared to obtain food at different places other than the home (in school and with friends), it appears that interventions aimed at improving childhood diets need to be multidimensional – considering the school environment, peers and social media [22].

Parental physical activity choices appeared to be more influenced by ease of participation and enjoyment of the activity rather than cultural relevancy, based on our data. This finding appeared to be consistent with other studies examining physical motivators in older individuals in other populations [23]. We nevertheless found this result surprising as previous studies have shown that South Asians reported cultural barriers to taking part in physical activity such as the inability to wear the religious dagger while swimming, and were more open to culturally-relevant activities such as yoga or Bhangra dance [8,24]. It is possible the same barriers reported here for physical activity such as lack of time and injuries might also impede the adoption of culturally-based physical activity such as Bhangra dance which can be vigorous in nature. Yet, evidence from this study suggests that physical activity is individualized for the adult South Asian population and thus, an understanding of individual context is necessary when trying to design interventions to improve physical activity in this group.

5.5.1. Implications

Our findings provide insights into a range of behavioural influences on South Asian children and their parents that may be worth considering when designing interventions for this population. Understanding the specific role that culture plays in the South Asian diet – particularly the heterogeneous nature of this diet and how this heterogeneity interacts with the dynamics of each family to predict food choices – could help health practitioners to better provide culturally-appropriate healthy dietary alternatives. For children, strategies aimed at encouraging or improving healthy behaviours must take into consideration the range of influences such as school environments, peers and social media that positively or negatively influence dietary and physical activity habits. In particular, given children's ubiquitous use of social media, its use as a possible intervention tool might offer a cost-effective and innovative approach to improving dietary and physical activity-related behaviour. However, care must be taken to avoid some of the pitfalls associated with social media use including its potential as a tool for advertising. Similarly, for South Asian parents, an understanding of motivators alongside barriers to dietary and physical activity behaviour change is important to understanding the unique individualized context. This knowledge will be useful in the development of effective population-level health promotion and other interventions aimed at promoting healthy behaviour.

5.5.2. Limitations

Given the small sample size results of this study may not be generalizable to other groups of South Asian children and parents. However, our approach was grounded in a culturally-sensitive framework, in addition to us having an adequate sample to achieve data saturation – qualities that might allow for the transferability of findings to other settings.

5.6. Conclusions

Despite the fact that studies have documented higher prevalence of CVD risk factors in South Asian children, qualitative research has been lacking on their attitudes and perspectives. We report findings from a qualitative study of South Asian children and their parents, documenting that a wide array of factors influence their perspectives – and the related behaviours. We found that both children and parents demonstrated adequate knowledge about the role of diet and physical activity in CVD development. However, that knowledge did not always translate into healthy behaviours. For children, school, peers and social media were observed to be the biggest influences on dietary and physical activity behaviours. For parents, in contrast, culture and health-related factors were the biggest influences on dietary and physical activity behaviours.

Consequently, intervention strategies in the South Asian child and adult populations must ensure that these factors are taken into account, if interventions are to yield meaningful, positive and sustained outcomes.

5.7. References

1. Rana A, de Souza RJ, Kandasamy S, Lear SA, Anand SS. Cardiovascular risk among South Asians living in Canada: a systematic review and meta-analysis. *CMAJ Open*. 2014; 2(3):E183-E191. doi:10.9778/cmajo.20130064

2. Jafar TH, Islam M, Poulter N, et al. Children in South Asia have higher body mass-adjusted blood pressure levels than white children in the United States: a comparative study. *Circulation*. 2005;111(10):1291-1297. doi:10.1161/01.CIR.0000157699.87728.F1

3. J Eyre EL, Duncan MJ, Nevill A. South Asian Children Have Increased Body Fat in Comparison to White Children at the Same Body Mass Index. *Children*, *4*(11), 102 doi:10.3390/children4110102

4. Owen CG, Nightingale CM, Rudnicka AR, Cook DG, Ekelund U, Whincup PH. Ethnic and gender differences in physical activity levels among 9–10-year-old children of white European, South Asian and African–Caribbean origin: the Child Heart Health Study in England (CHASE Study). *Int J Epidemiol*. 2009; 38(4):1082-1093. doi:10.1093/ije/dyp176

5. Fischbacher CM, Hunt S, Alexander L. How physically active are South Asians in the United Kingdom? A literature review. *J Public Health*. 2004; 26(3):250-258. doi:10.1093/pubmed/fdh158

6. Chapman J, Qureshi N, Kai J. Effectiveness of physical activity and dietary interventions in South Asian populations: A systematic review. *Br J Gen Pract*. 2013; 63(607):e104-114. doi:10.3399/bjgp13X663064

7. Patel M, Phillips-Caesar E, Boutin-Foster C. Barriers to lifestyle behavioral change in migrant South Asian populations. *J Immigr Minor Heal*. 2012; 14(5):774-785. doi:10.1007/s10903-011-9550-x

8. Farooqi A, Nagra D, Edgar T, Khunti K. Attitudes to lifestyle risk factors for coronary heart disease amongst South Asians in Leicester: a focus group study. *Fam Pract*. 2000; 17(4):293-297. doi:10.1093/fampra/17.4.293

9. Airhihenbuwa CO, Ford CL, Iwelunmor JI. Why Culture Matters in Health Interventions: lessons from HIV/AIDS stigma and NCDs. *Heal Educ Behav*. 2013; 41(1):78-84. doi:10.1177/1090198113487199

10. Banerjee AT, Flora PK, Stone M, Faulkner G. Differences in the Prevalence of Overweight Between 10-12-Year-old South Asian and Non-South Asian Children in Toronto, Ontario: Findings from Project BEAT. *J racial Ethn Heal disparities*. 2015; 2(2):184-191. doi:10.1007/s40615-014-0062-y

11. Saxena S, Ambler G, Cole TJ, Majeed A. Ethnic group differences in overweight and obese children and young people in England: cross sectional survey. *Arch Dis Child*. 2004; 89(1):30-36.

12. Resnicow K, Baranowski T, Ahluwalia JS, Braithwaite RL. Cultural sensitivity in public health: defined and demystified. *Ethn Dis*. 1999;9(1):10-21.

13. Tariq S, Woodman J. Using mixed methods in health research. *JRSM Short Rep*. 2013; 4(6):2042533313479197. doi:10.1177/2042533313479197

14. Fowokan AO, Punthakee Z, Waddell C, et al. Adiposity measures and their validity in estimating risk of hypertension in South Asian children: a cross-sectional study. *BMJ Open*. 2019; *9*(2):e024087. doi:10.1136/bmjopen-2018-024087

15. Kirk S. Methodological and ethical issues in conducting qualitative research with children and young people: A literature review. *Int J Nurs Stud*. 2007; 44(7):1250-1260. doi:10.1016/j.ijnurstu.2006.08.015

16. Fereday J, Muir-Cochrane E. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *Int J Qual Methods*. 2006; 5(1):80-92. doi:10.1177/160940690600500107

17. Lilo EA, Muñoz M, Cruz TH. Perceptions of Healthy Eating Among Hispanic Parent–Child Dyads. *Health Promot Pract*. 2019; 20(2):231-238. doi:10.1177/1524839918761866

18. Protudjer JLP, Marchessault G, Kozyrskyj AL, Becker AB. Children's perceptions of healthful eating and physical activity. *Can J Diet Pract Res*. 2010; 71(1):19-23. doi:10.3148/71.1.2010.19

19. Savage JS, Fisher JO, Birch LL. Parental influence on eating behavior: conception to adolescence. *J Law Med Ethics*. 2007; 35(1):22-34. doi:10.1111/j.1748-720X.2007.00111.x.Parental

20. Birman D, Poff M. Intergenerational Differences in Acculturation. *Encycl Early Child and dev.* 2011:1-8.

21. Tiedje K, Wieland ML, Meiers SJ, et al. A focus group study of healthy eating knowledge, practices, and barriers among adult and adolescent immigrants and refugees in the United States. *Int J Behav Nutr Phys Act*. 2014; 11(1): 63. doi:10.1186/1479-5868-11-63

22. Black AP, D'Onise K, McDermott R, Vally H, O'Dea K. How effective are family-based and institutional nutrition interventions in improving children's diet and health? A systematic review. *BMC Public Health*. 2017;17(1):818. doi:10.1186/s12889-017-4795-5

23. Allender S, Cowburn G, Foster C. Understanding participation in sport and physical activity among children and adults: A review of qualitative studies. *Health Educ Res*. 2006; 21(6):826-835. doi:10.1093/her/cyl063

24. Jepson R, Harris FM, Bowes A, Robertson R, Avan G, Sheikh A. Physical Activity in South Asians: An In-Depth Qualitative Study to Explore Motivations and Facilitators. *PLoS One*. 2012;7(10): e45333. doi:10.1371/journal.pone.0045333

Chapter 6.

Further Discussion and Conclusion

6.1. Objectives and Main Findings

The overarching objective of this mixed methods research was to develop a better understanding of how broad-based (physiological, lifestyle, social and cultural) factors, influence blood pressure (BP) in South Asian children.

To address the overarching objective, this thesis comprised four linked objectives: 1) to conduct a systematic review of the literature to explore the various factors that predict elevated BP in children and adolescents (Chapter 2); 2) to explore the associations between physiological, lifestyle and social factors and BP in South Asian children, and to identify the most important aggregate correlates of BP in South Asian children (Chapter 3); 3) to explore the association between adiposity measures with BP and hypertension in South Asian children, to compare the accuracy of these indicators in estimating the risk of hypertension, and to explore the adiposity cut-off values of these indicators associated with adverse risk for hypertension in South Asian children (Chapter 4); and 4) to qualitatively understand attitudes, perceptions and knowledge about physical activity, diet and CVD risk in children and parents, including potential cultural influences as a means to guide potential intervention studies in this population (Chapter 5).

6.1.1. Main findings from Chapter 2

- A broad range of physiological, social and behavioural factors were associated with elevated BP in children; the most common correlate observed was adiposity, suggesting childhood obesity may be implicated in the increased prevalence of hypertension observed in children.
- The presence of other physiological factors (such as age, height, sex, sexual maturity and cardiorespiratory fitness), behavioural factors (such as sedentary behaviour and unhealthy dietary choices) and social factors (such as ethnicity, socioeconomic status, stress and neighbourhood) underscores the multifactorial etiology of hypertension in children.

6.1.2. Main findings from Chapter 3

- Variables such as age, adiposity, sex, heart rate, height, child's perception of body image and acculturation were associated with systolic BP z-score in unadjusted analysis, while age, height, heart rate, father's education, total daily food intake, fast food consumption and grip strength were associated with diastolic BP z-score in South Asian children.

- In stepwise regression models, the combination of age, sex, BMI z-score, heart rate and weight accounted for 30% of the systolic BP z-score variance of South Asian children; likewise, the combination of age, BMI z-score, heart rate and daily intake of fast foods accounted for 23% of the diastolic BP z-score variance of South Asian children.

6.1.3. Main findings from Chapter 4

- The prevalence of hypertension in this convenience sample of 762 South Asian children was found to be high at 12%.

- Consistent associations were observed between adiposity indicators such as BMI, WC, WHtR Z-score, and BIA-estimated body fat with BP z-score and hypertension in both unadjusted and adjusted models.

- The area under the ROC curve values for the adiposity indicators for South Asian boys and girls ranged from 0.74-0.80, suggesting the adiposity indicators ranged from fair to good in their accuracy of estimating hypertension risk.

- Sex-specific cut-off for the adiposity indicators associated with adverse risk of hypertension for girls and boys suggest South Asian boys and girls might be at risk of hypertension at levels of adiposity considered normal in reference populations.

6.1.4. Main findings from Chapter 5

- Four main themes characterizing the attitudes and perspectives of both children and parents regarding healthy behaviours implicated in cardiovascular health were identified: knowledge about heart disease, attitudes towards diet, attitudes towards physical activity, and other factors.

- Both children and parents demonstrated good knowledge about CVD risk factors but this knowledge did not always translate into the practice of healthy behaviours.

- Children also documented a range of influences on physical activity and dietary behaviours such as schools, peers and social media.

- For parents, health reasons appeared to be the most important influence on behaviour, the influence of family and cultural dynamics on South Asian diets was also highlighted.

The following sections highlight relevant issues relating to South Asian ethnicity and hypertension, noteworthy discussions and implications of these findings in aggregate.

6.2. General Discussion and Commonalities in Findings

This thesis aimed to develop a detailed understanding of how broad-based factors influence the risk of elevated BP and hypertension in South Asian children through four linked objectives. Although each chapter had a distinct objective, findings from each chapter incrementally fed into the next, culminating in a robust understanding of both the burden of hypertension in this population of South Asian children and its associated risk factors.

The systematic review conducted in Chapter 2 provided the knowledge backdrop for the research objectives explored in Chapters 3 and 4 of this thesis. Findings from the systematic review highlighted the range of physiological, behavioural and social factors that were associated with elevated BP and hypertension, providing support for a multifactorial basis for elevated BP and hypertension in the child population. In Chapter 3, I sought to examine if the multifactorial associations observed in the systematic review held true in this population of South Asian children. Findings from Chapter 3 documented associations between physiological variables such as age, sex, height, heart rate, adiposity and grip strength with elevated BP and hypertension, and limited associations between social and lifestyle variables which disappeared upon adjustment for sociodemographic factors. This suggests that for South Asians, physiological variables like adiposity provide better explanatory capacity regarding the increased risk of elevated BP and hypertension than lifestyle and social variables, and that the multifactorial basis for hypertension is largely dependent on the age and sex of the child and socio-economic status of the family. It should be noted that while behavioural factors like diet and physical activity were not found to be associated with elevated BP and hypertension, these factors are known determinants of obesity [1]. Therefore attempts aimed at addressing increased adiposity in South Asian children must also target these factors.

Moreover, as identified from the findings of the systematic review, the most recurring and consistent correlate of elevated BP and hypertension was found to be adiposity measures. This was observed across the range of adiposity measures assessed: including BMI, WC, WHtR, dual energy x-ray absorptiometry measures and others. In Chapter 4, I sought to confirm the consistency of the association between adiposity with elevated BP and hypertension in South Asian children using a range of common adiposity metrics. Additionally, given the unique adiposity profile observed in South Asians, I sought to observe if these metrics were valid in identifying adverse risk of hypertension in South Asian children and if so, what thresholds of these metrics were associated with adverse hypertension risk. The findings from Chapter 4 appear consistent with evidence from the systematic review, confirming theories that attribute the increased prevalence of hypertension to the concomitant increase in levels of adiposity in children. Furthermore, the findings question the validity of a single threshold for screening obesity and cardio-metabolic risk in all children, and provide cut-off values that could be useful in identifying at-risk South Asian children clinically. Importantly, results from Chapter 4 combines with the findings from Chapter 3 to improve our understanding of the epidemiology of elevated BP and hypertension in South Asian children.

Given the evidence obtained from Chapters 3 and 4 on the high prevalence of hypertension in South Asian children and the contribution of factors like adiposity to its burden, I sought to understand attitudes toward healthy behaviours in South Asian children and the array of factors that act to influence these behaviours. Moreover, because parents' attitude towards diet and physical activity related behaviours has been shown to influence children's behaviours, I sought to explore the combined perspective of children and their parents. To do this, I conducted qualitative interviews with 13 child-parent dyads. The analyses of the qualitative interview data provide insight into the multi-dimensional factors that shape healthy behaviours in South Asian children and their parents. These findings help to contextualize the results from Chapters 3 and 4 by providing insights into the specific influences that might result in increased cardio-metabolic risk. Understanding the specific influences of these factors on the behaviour of South Asian children can help with the development of effective, culturally-sensitive interventions that consider the unique socio-cultural influences that affect uptake of healthy behaviors such as healthy diet and physical activity, thereby addressing disproportionate CVD risk in South Asians. Accordingly, findings from Chapters 3, 4 and 5 in aggregate not only present novel findings documenting the epidemiology of hypertension in South Asian children, but also provide valuable qualitative information, to guide intervention efforts aimed at addressing modifiable correlates for elevated BP and hypertension.

To conclude, the information presented in each chapter of this thesis coalesces to provide a novel understanding of the epidemiology of elevated BP and hypertension in South Asian children living in Canada. Given the disproportionate burden of CVD risk factors and outcomes that has been widely documented in South Asian adults, including for hypertension [2, 3], in addition to evidence of BP tracking from childhood to adulthood [4], this information has vital public health importance. Likewise, the findings from Chapter 5 augment results from Chapters 3 and 4 by identifying the array of social and cultural influences that influence CVD-related behaviours in children and their parents. The novel contributions provided by results from Chapter 5 also further help to inform the development of effective interventions that target modifiable risk factors such as adiposity on hypertension risk. Ultimately, these findings could help in the identification and prevention of hypertension in South Asian children, in turn helping to prevent the tracking of hypertension into adulthood and addressing the disproportionate CVD burden experienced in the South Asian population.

6.3. Thesis Limitations

While the RICH-LEGACY study provided ample data on a range of proximal variables (variables with direct effects on health) such as the physiological, behavioural and social risk factors included in this study, distal variables (variables with indirect effects on health) such as neighbourhood-level and environmental risk factors which were also shown in the systematic review to be associated with hypertension were lacking. This meant that we were limited to exploring the effect of mostly proximal variables in our regression models and unable to explore the distal ones given our lack of data. Yet, to fully understand risk distribution in this population, analytical frameworks that consider the effect of both proximal and distal variables in regression models will be necessary. This is important given the connections between the built environment and health behaviours which tend to impact on risk factors like adiposity. As a result, a robust data set which includes both the proximal and distal variables identified in the systematic review and utilizes analytical frameworks that considers both the contribution of proximal and distal variables in regression analysis might be better suited to improving our knowledge of the etiology of hypertension in South Asian children.

6.4. Implications of Findings

Findings from this thesis document a disproportionately-increased prevalence of hypertension in South Asian children relative to estimates reported in Canadian children more generally [5]. These findings also document that South Asian children may be at risk for hypertension at levels of adiposity that are considered normal in the child population – suggesting that healthcare practitioners may be unable to identify at-risk South Asian children using current guidelines. These findings, combined with the qualitative findings reported here, underscore the importance of interventions being aimed at addressing the disparate risk for South Asians by improving the identification of at-risk South Asian children and addressing the burden of hypertension in these children. Given the cardio-metabolic sequelae of hypertension and the evidence of BP tracking into adulthood, such interventions will in turn positively affect the CVD burden in South Asians of all ages.

Based on the described findings, three recommendations are highlighted for consideration.

- First, while results suggesting that South Asian children may be at risk of hypertension at "normal" adiposity levels require prospective confirmation, the profoundness of this finding requires action. Given that the adiposity indicators utilized in this thesis are those that are most commonly used in assessing adiposity in all children, utilizing the cut-offs provided to assess risk in South Asian children offers a cost-effective and pragmatic way to monitor and prevent hypertension risk in South Asian children.

- Second, the risk factors for elevated childhood BP and hypertension documented in Chapter 4 – including male sex, increased heart rate, taller height, greater adiposity or having a combination of these factors – provides health practitioners valuable information on South Asian children that can inform clinical care as well as informing the development of population-level interventions aimed at addressing hypertension risk.

- Third, the results from the qualitative study, rooted in a cultural framework, could guide the development of effective interventions that consider the influence of culturally-relevant factors aimed at improving behaviour change. These potentially include the use of social media as a tool to promote healthy eating and physical activity in children, or a multi-dimensional approach that modulates the influences of peers, school and the family environment on behaviour and that actively works to positively target these influences.

Given the importance of behavioural factors for cardio-metabolic health, addressing these factors early in life offers a promising approach – addressing unhealthy behaviours before they become firmly rooted.

6.5. Future Research

This thesis provides novel information highlighting the distribution and correlates of hypertension in a population of South Asian children living in Canada. Yet, to definitively show that South Asians experience a disproportionate risk for hypertension relative to other ethnic groups will require a multi-ethnic study that allow for comparisons of risk under similar data conditions. Moreover, the cross-sectional nature of this study limits its definitive capacity to suggest diagnostic changes regarding cut-offs used to identify cardio-metabolic risk in South Asian children. A prospective study that explores adiposity changes in relation to hypertension in South Asian children is needed to provide information that clearly validates the prognostic utility of ethnic-specific cutoffs in screening for cardio-metabolic risk in children. It is also unclear how much of the variance in BP for south Asian is accounted for by heritable factors. A better understanding of the heritability of elevated BP and hypertension will help provide a detailed epidemiological picture on the risk for hypertension in South Asian children.

6.6. References

1. Raychaudhuri M, Sanyal D. Childhood obesity: Determinants, evaluation, and prevention. Indian journal of endocrinology and metabolism. 2012;16(Suppl 2):S192.

2. Rana A, Anand SS, Lear SA, de Souza RJ, Kandasamy S. Cardiovascular risk among South Asians living in Canada: a systematic review and meta-analysis. C Open. 2014;2(3):E183-E191. doi:10.9778/cmajo.20130064

3. Anand SS, Yusuf S, Vuksan V, et al. Differences in risk factors, atherosclerosis, and cardiovascular disease between ethnic groups in Canada: the Study of Health Assessment and Risk in Ethnic groups (SHARE). Lancet. 2000;356(9226):279-284. doi:10.1016/S0140-6736(00)02502-2

4. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: A systematic review and meta-regression analysis. Circulation. 2008; 117(25): 3171-3180. Doi:10.1161/CIRCULATIONAHA.107.730366.

5. Statistics CANADA. Blood pressure of children and youth, 2012 to 2015. https://www150.statcan.gc.ca/n1/pub/82-625-x/2016001/article/14659-eng.htm. Published 2016.

Appendix A.1

Systematic Review Data Extraction

<u>Table of contents</u>

Systematic review search strategy

1. Hypertension
2. "Blood pressure"
3. "Systolic blood pressure"
4. "Diastolic blood pressure"
5. HTN
6. SBP
7. DBP
8. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8
9. Child*
10. Youth
11. Adolescen*
12. Juvenile
13. Teen*
14. Kid*
15. Infant*
16. Boy*
17. Girl*
18. 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17
19. Determinant
20. Predictor
21. Risk factor
22. Etiology
23. Aetiology
24. 19 OR 20 OR 21 OR 22
25. 8 AND 18 AND 24

Table A.1: Physiological correlates of BP

Study (country)	Study design	Study Characteristics	Measurement of BP	Risk factors	Covariates
Adair et al (Philippines)	Prospective cohort	Participants for this study were recruited as part of the ongoing Cebu Longitudinal Health and Nutrition survey (CLHNS). This study followed a cohort of 3080 infants born in 1983 and 1984 and followed them up until 1998-2000. Additionally, mothers also assessed at about 30 weeks of gestation at baseline for dietary composition and other variables. A total of 2026 children had complete measurements at followed up and form the basis for this analysis.	Mercury sphygmomanometer	Boys SBP (mmHg): Maternal BP (β =0.07, p≤0.01; Maternal triceps skinfold thickness (β= -0.31, p≤0.01); birth weight (β= -1.74, p≤0.10) DBP (mmHg): Maternal triceps skinfold thickness (β= -0.21, p≤0.05); Maternal BP (β =0.07, p≤0.01 Girls SBP (mmHg): Maternal BP (β =0.06, p≤0.01); Maternal % energy from fat (β = -0.08, p≤0.01) DBP (mmHg): Maternal BP (β =0.04, p≤0.01); Maternal % energy from fat (β = -0.07, p≤0.05); Birth length (β = -0.34, p≤0.05)	Current age, height, BMI
Akis et al (Turkey)	Case-control	This study includes 236 participants (118 hypertensive and 118 age and sex matched non hypertensive controls) aged 12-14 years old recruited from a previous cross	Oscillometric device SBP and/or DBP between 95th and 99th	Hypertension vs normal: Risk of overweight (BMI at the 85–94th percentile) (OR=5.65 95% CI 2.88-11.09), p<0.001	Paraoxonase, dyslipidemia, phenotype

		sectional study conducted in middle school children. Study participants were screen for demographic information, lifestyle factors, anthropometry and metabolic CVD risk factor.	percentile was described as hypertension, SBP and/or DBP under 90th percentile was defined as normal		
Barba et al (Italy)	Cross sectional	4514 prepubertal children aged 6-11 years were recruited from 19 primary schools from a district in Southern Italy. Data on anthropometry, physical activity and BP was obtained by trained staff. The study explores gender differences in the association between age and BP.	Mercury sphygmomanometer	<u>Girls</u> SBP z scores: age (β = 0.083, p = 0.004; adjusted R^2 = 0.17) DBP z scores: age (β = 0.063, p = 0.03 R^2 = 0.10) <u>Boys</u> No significant relationship observed	Height, waist circumference
Bergel et al (Argentina)	Prospective cohort	518 newborn children born to nulliparous women who were previously part of a calcium supplementation RCT, and followed up for 5 to 9 years.	Random zero sphygmomanometer	SBP (mmHg): Hemoglobin at 20 weeks gestation positively associated with (1.3 (95%CI 0.4-2.3) Stratified analysis by BMI quartiles found low birth weight was 14.8mmHg (95% CI 3.3-26.4) higher in children within upper BMI quartiles	Sex, age at follow up, BMI, Maternal treatment group Sex, age, height and maternal treatment group.
Bergmann et al	Cross	This study includes	Manual	<u>Independent effects model</u>	Sex

(Brazil)	sectional	1442 children aged 7-12 years old recruited from public and private elementary schools in a Brazilian city using a two stage clustered sampling approach. Participants were assessed for measures of cardiorespiratory fitness, adiposity and BP. The combined association between cardiorespiratory fitness and fatness with BP was explored.	sphygmomanometer Increased SBP/DBP defined as BP in the prehypertension/hypertension range according to NHBEP cut-offs.	Increased SBP: BMI (Overweight vs normal) (OR= 2.55, 95% CI 1.58, 4.18) p=0.000, % fat (increased fat vs normal) (OR= 2.24, 95% CI 1.26, 3.98) p=0.006, cardiorespiratory fitness (unfit vs fit) (OR= 1.63, 95% CI 1.07, 2.49) p= 0.024 Increased DBP: BMI (Overweight vs normal) (OR= 1.50, 95% CI 1.01, 2.24) p=0.046, (obese vs normal) (OR= 2.53, 95% CI 1.36, 4.72) p=0.003, CRF (unfit vs fit) (OR= 1.87, 95% CI 1.33, 2.61) p=0.000 Combination of fitness and fatness models Increased SBP: Overweight/fit (OR=3.47, 95% CI 1.75, 6.90) p=0.000, overweight/unfit (OR= 5.34, 95% CI 2.87, 9.93) Increased DBP: Overweight/fit (OR=2.09, 95% CI 1.22, 3.59) p=0.007, overweight/unfit (OR= 3.63, 95% CI 2.27, 5.80) p=0.000	
Blake et al (Australia)	Prospective cohort	Participants in this study were recruited as part of the western Australian pregnancy cohort, a birth cohort of mothers with singleton pregnancies recruited	Oscillometric monitor	SBP (mmHg): Birth weight {β= -2.3 (95% CI -3.3, -1.3), p<0.01}	Current weight

		during gestation. Association between birth weight and BP was explored, adjusted for current weight.			
Bohlke et al (Brazil)	Cross sectional	443 children aged 3-12 years old were recruited from pediatric outpatient clinic in Brazil and assessed for anthropometric variables, socio-demographic characteristics, clinical factors (birth weight obtained from health registry) and BP. The correlates of BP in children were explored.	Auscultatory method	SBP (mmHg): Birth weight (β= -0.007, SE= 0.002, p=0.002), BMI percentiles (β= 2.43, SE= 0.73, p=0.001) DBP (mmHg): Age (β= -0.006, SE= 0.003, p=0.03), Birth weight (β= -0.003, SE= 0.0001, p=0.02), BMI percentiles (β= 0.09, SE= 0.04, p=0.05	
Bonamy et al (Sweden)	Case-control study	60 Swedish children (39 born preterm and 21 control born at term) aged 7-12 years were included in this study. Participants were recruited through maternity wards and by searching hospital birth records. Participant were assessed for a range of clinical measures including capillary density, endothelial function and	Oscillometric device	<u>Model 1</u> SBP (mmHg): Preterm (β=2.6, SE= 1.0 p= 0.010), female (β=2.3, SE= 0.9, p=0.012), Height, per cm (β=0.39, SE= 0.09 p<0.0001, family history of cardiovascular disease (β=3.4, SE= 1.3, p= 0.011 R^2 = 0.37	Gender, height

		BP. The association between skin capillary density, endothelial function and BP was investigated.			
Brady and Matthews (America)	Cross sectional	217 adolescents aged 14 to 16 years were recruited from two urban high schools in Pennsylvania, US. Participants were assessed for information on stressful life events, and their association with ambulatory blood pressure measurements was explored.	Accutracker Dx ambulatory blood pressure monitor	SBP (mmHg): chronic negative life events t= 2.48, p = .01 DBP (mmHg)= Chronic life events x sex, t = 2.60, p = 0.01 Chronic life events x boys , t = 2.07, p= 0.04	Ethnicity, sex, BMI, location, position, physical activity, and consumption of food/caffeine/nicotine.
Brambilla et al (Italy)	Retrospective cohort	A total of 2639 children were selected by extracting data from family pediatricians in Italy based on the following criteria: 1) born at term 2) born a singleton 3) ≥ 6 years and ≤ 11 years old 4) Parents with good Italian speaking skills. Of the eligible children, 1294 Caucasian children represented the final sample after	Manual sphygmomanometer	SBP z scores: birth weight z score (β= -0.06 (95% CI -0.11, -0.01) p< 0.05); BMI z score (β= 0.17 (95% CI 0.12, 0.21) p< 0.001); Complementary feeding at 5 months (β= -0.38 (95% CI = -0.47, -0.29) p< 0.001); Mother with low education (β= -0.13 (95% CI -0.24, -0.01) p < 0.05) DBP z scores: age (β= -0.04 (95% CI 0.01, 0.07) p< 0.01); BMI z score (β= 0.10 (95% CI 0.06, 0.14) p< 0.001);	Multivariable regression included: gender, age, birth weight, BMI, Breast feeding (≥ 6 months), complementary feeding (≤ 5 months), physical activity, screen time, mother's low education, parental smoking, parental obesity, parental hypertension

		meeting the full screening criteria,		Complementary feeding at 5 months (β= -0.32 (95% CI = -0.40, -0.24) p< 0.001); Mother with low education (β= -0.12 (95% CI -0.22, -0.02) p < 0.05); birth weight z score (β= -0.05 (95% CI -0.09, -0.001) p< 0.05); hypertensive parent (β= 0.11 (95% CI 0.01, -0.22) p< 0.05)	
Brion et al (England)	Cross sectional	Participants in this study were enrolled in the Avon longitudinal study of parents and children, a prospective cohort study investigating health and development of children. For this present study, 6863 children (3401 boys, 3462 girls) with data on anthropometric characteristics, DEXA, and BP were included.	Oscillometric device	SBP (mmHg): Total fat mass{β= 3.29 (95% CI 3.02 to 3.57) p<0.001} R= 0.21; Total lean mass {β= 3.38 (95% CI 2.95, 3.81) p<0.001} R= 0.17 ;Trunk fat {β=3.23 (95% CI 2.96 to 3.50) p<0.001} R= 0.21; BMI at 9 years {β=3.97 (95% CI 3.73 to 4.21) p<0.001} R= 0.19 DBP (mmHg): Total fat mass {β= 1.26 (95%CI 1.05, 1.46) p=0.001} R= 0.08; Trunk fat {β=1.22 (95% CI 1.02, 1.42) P<0.001} R= 0.08; BMI at 9 years {β=1.37 (95% CI 1.19, 1.54) p<0.001} R= 0.07	Height, age, sex, birth weight, gestational age, room temperature, time of day, demeanour, social class, maternal education, maternal age, maternal hypertension, parity, maternal BMI and maternal height
Burgos et al (Brazil)	Cross sectional	1950 children (1048 female, 902 male) aged 7-18 years were randomly recruited from 16 schools in Santa Cruz do Sul, Brazil and	Aneroid sphygmomanometer	SBP (mmHg): Age (β= 1.826, 95% CI 1.596, 2.055, p<0.001), BMI (β= 0.841, 95% CI 0.539, 1.143, p<0.001), WC (β= 0.226, 95% CI 0.105, 0.347, p<0.001)	

		assessed for anthropometric variables, and cardio metabolic risk factors. The association between anthropometric variables and cardio metabolic risk factors was explored.		DBP (mmHg): Age (β= 1.319, 95% CI 1.120, 1.519, p<0.001), BMI (β= 0.512, 95% CI 0.249, 0.774, p<0.001), WC (β= 0.166, 95% CI 0.061, 0. 271, p<0.001)	
Chirico et al (Canada)	Cross sectional	Participants for this study were recruited as part of the Heart Behavioural Environment Assessment Team. A total of 1913 children ages 11-14 years were recruited across 50 schools. From this sample, a random sub-sample (n=224) children were recruited and stratified across BP levels. The current analysis includes 106 participants who took part in laboratory analysis, and BP measurements, and who fell into either the normotensive or the hypertensive group.	Oscillometric device Participants were classified into one of three BP groups based on the sample distribution after adjusting for age, sex and height; normotensive (NTN) if systolic and/or diastolic BP (SBP and DBP, respectively) were <90th percentile; or hypertensive (HTN) if SBP and/or DBP was ≥95th percentile	BP group (hypertensive vs normotensive): Heart rate OR 1.13 (95% CI1.06–1.22) p<0.001, BMI OR 1.32 (95% CI 1.15–1.52) p<0.001	
Cho et al	Cross	383 participants (179	Mercury	Boys	Generalized linear model

(America)	sectional	boys and 204 girls) aged 11 to 16 years recruited as part of the Heartfelt study were assessed for a range of variables including tanner staging, anthropometry and BP was assessed. The study explores association between sexual maturity, anthropometry and BP.	Sphygmomanometer	SBP (mmHg): Height (β= 0.227, p=0.0081), BMI (β= 0.461, p=0.0021), Ethnicity (African-American vs European) (β= -6.338, p=0.0004), (Hispanic-American vs European) (β= -1.800, p=0.0004), Maturity (β= 2.829, p=0.0477), Age (β= 2.062, p=0.0007) R^2= 0.392 <u>Girls</u> SBP (mmHg): BMI (β= 0.243, p=0.0243), Maturity (β= 3.268, p=0.0072), Age (β= 1.133, p=0.001) R^2= 0.221	
Colin-Ramirez et al (Mexico)	Cross sectional	This study included children 1239 participants (626 boys and 613 girls) aged 8 to 10 years recruited from a convenience sample of 23 public schools of in Mexico City. Participants were screen for diet, physical activity, anthropometry and BP. The association between anthropometry and dietary intake with BP was investigated.	Aneroid sphygmomanometer systolic hypertension: SBP ≥95th percentile for age, sex, and height, without diastolic prehypertension or hypertension; diastolic hypertension: DBP ≥95th percentile for age, sex, and height	Systolic hypertension: Age {OR= 0.58 (95% CI 0.35, 0.94) p<0.05}, diastolic blood pressure {OR= 1.14 (95% CI 1.10, 1.17) p<0.001}, waist circumference {OR= 1.06 (95% CI 1.01, 1.11) p<0.05} Diastolic hypertension: Systolic blood pressure {OR= 1.14 (95% CI 1.11, 1.18) p<0.001}, Total fat intake >35% {OR= 2.61 (95% CI 1.27, 5.36) p<0.01}.	Age, sex, DBP/SBP

Correia-Costa et al (Portugal)	Cross sectional study	Participants for this study were recruited as part of the Generation XXI cohort. At four years of age, the cohort was re-examined, and 1250 children (609 girls, and 641 boys) who had no renal, or metabolic disorders were assessed for full blood profile, anthropometric characteristics, and BP. The association between adiposity and BP, and the potential mediating role of fasting insulin was explored.	Aneroid sphygmomanometer	<u>Girls</u> SBP (mmHg): BMI Z score {β= 2.68 (95% CI 2.14, 3.21) p<0.001}, explained 84.5% of the model effect. Mediation effect of Insulin resistance {β= 0.40 (95% CI 0.19, 0.60) p<0.001}, explained 12.6% of the model effect. DBP (mmHg): BMI Z score {β= 1.52 (95% CI 0.96, 2.08) p<0.001}, explained 81.7% of the model effect. Mediation effect of Insulin resistance {β= 0.25 (95% CI 0.02, 0.48) p=0.033}, explained 13.5% of the model effect. Model 2 SBP (mmHg): waist-height ratio {β= 0.505 (95% CI 0.356, 0.654) p<0.001}, explained 74.1% of the model effect. Mediation effect of Insulin resistance {β= 0.14 (95% CI 0.093, 0.187) p<0.001}, explained 20.5% of the model effect. DBP (mmHg): waist-height ratio {β= 0.308 (95% CI 0.156, 0.459) p<0.001}, explained 72.8% of the model effect. Mediation effect of Insulin resistance {β= 0.085 (95% CI 0.031, 0.138) p<0.002}, explained 20.1% of the	PATH analysis used. Models adjusted for family history of hypertension. Waist to height ratio model additionally adjusted for age in months.

				model effect <u>Boys</u> SBP (mmHg): BMI Z score {β= 2.44 (95% CI 1.86, 2.00) p<0.001}, explained 93.1% of the model effect. Mediation effect of Insulin resistance {β= 0.17 (95% CI 0.02, 0.31) p= 0.027}, explained 6.5% of the model effect. DBP (mmHg): BMI Z score {β= 1.92 (95% CI 1.51, 2.32) p<0.001}, explained 95.5% of the model effect. Model 2 SBP (mmHg): waist-height ratio {β= 0.615 (95% CI 0.486, 0.745) p<0.001}, explained 90.2% of the model effect. Mediation effect of Insulin resistance {β= 0.064 (95% CI 0.024, 0.105) p=0.002}, explained 9.4% of the model effect. DBP (mmHg): waist-height ratio {β= 0.687 (95% CI 0.561, 0.812) p<0.001}, explained 95.8% of the model effect. Mediation effect of Insulin resistance {β= 0.036 (95% CI 0.001, 0.071) p= 0.046}, explained 5.0% of the model effect	

Dasgupta et al (Canada)	Prospective cohort	Using an adolescent cohort (n=1267) this study followed up boys and girls for a period of five years to assess sex differences in risk factors for elevated systolic blood pressure.	Oscillometric device	Boys SBP (mmHg) (≥90th percentile): Age OR= 1.19 (95%CI 1.05, 1.36); Heart rate (5bpm increment) OR= 1.28 (95% CI 1.16, 1.42); Overweight OR= 3.04 (95% CI 1.80, 5.13); TV/ video games (increment, 5hours/week) OR= 1.24 (95% CI 1.08, 1.41); French vs English as first language OR= 3.58 (95% CI 1.39, 9.17) Girls SBP (mmHg) (≥90th percentile): Heart rate (5bpm increment) OR= 1.22 (95% CI 1.10, 1.37); Overweight OR= 2.25 (95% CI 1.27, 4.00); French vs English as first language OR= 3.05 (95% CI 1.08, 8.61) INTERACTION SBP: Sex (Girls as reference) x Age (p= 0.03); Sex x tobacco (p=0.03)	Generalized estimation equations logistic regression model that included; Age, heart rate, overweight, activities, TV/video games, Alcohol, French vs English, Both languages vs English, other vs English, household income
De Onis et al (Spain)	Cross sectional study	149 (99 boys and 50 girls) children and adolescents aged 8-18 years were recruited from pediatric centres in Valencia, Spain. Participants were assessed for anthropometric, characteristics, and the	Oscillometric device High BP defined as average SBP and/or DBP ≥95TH percentile for age, sex and height	High BP: (Obese group compared to normal weight reference group) OR= 10.92 (95% CI 1.32, 90.13) p<0.05	Age, and sex

		association between these variables and blood pressure was explored.			
Dinc et al (Turkey)	Cross sectional	1346 high school children aged 15-18 in Manisa, Turkey were recruited into this study and assessed using a survey tool for anthropometric characteristics and BP.	Standard sphygmomanometer Hypertension is defined as SBP and/or DBP that is ≥95th percentile for sex, age and height percentile	Hypertension vs Normal: BMI ≥ 95^{TH} percentile (OR= 7.60 95% CI 2.90, 19.89) p=0.001, BMI 85^{th} to 95^{th} percentile (OR= 5.09 95% CI 2.57, 10.07) p=0.001 R^2 value= 0.083	Age, sex, income, family history of hypertension
Dong et al (China)	Cross sectional	4898 students' ages 6 to 17 years were recruited from Shandong province in Eastern China. Recruited participants had to have lived in the province with parents or guardian for a minimum of 6 months.	Electronic sphygmomanometer	BMI categories Non-overweight: Average SBP (mmHg) = 106 ± 12; Average DBP = 67± 8; High BP = 11%; OR (95% CI) = 1.0 (reference) Overweight: Average SBP (mmHg)= 111 ± 13; Average DBP = 70± 9; High BP = 25%; OR (95% CI) = 2.2 (1.7, 2.8) Obesity: Average SBP = 113 ± 15; Average DBP = 74± 11; High BP = 39%; OR (95% CI) = 3.6 (2.6, 4.9)	Age, and gender
Dong et al (China)	Cross sectional	82 413 (40 988 boys and 41 425 girls) multi ethnic Chinese children aged 9-17	Mercury sphygmomanometer	Hypertension: Normal weight (WC <75th percentile): {OR = 1.42, 95% CI 1.30, 1.55}, Abdominally over weight (WC ≥75th percentile): {OR =	Sex, age, urban/rural area, province, time for physical activity, homework time and

		years were recruited through multi stage sampling from primary and secondary schools from 30 provinces to participate in the Chinese National Survey on Students Constitution and Health (CNSSCH). The association between WC and hypertension in children with normal weight was compared with that in abdominally overweight children.	Hypertension defined as SBP or DBP at the 95th percentile for sex, age and height.	1.74, 95% CI 1.66, 1.82}, p<0.001	screen time.
Dulskiene et al (Lithuania)	Cross sectional	A total of 7486 participants (3510 boys, 3976 girls) aged 12 to 15 year old recruited from secondary schools and gymnasiums were assessed for anthropometric and BP measurements.	Oscillometric device (OMRON M6) Normal BP was defined as SBP and DBP <90th percentile; prehypertension was defined as average SBP or DBP levels between the ≥90th percentile and the <95th percentile; and hypertension was defined as average SBP or DBP readings ≥95th percentile	Prehypertension: BMI categories (Overweight vs normal weight) OR 2.62(95% CI 2.13–3.23) p< 0.001, (Obesity vs normal weight) OR 4.81 (95% CI 3.08 –7.52) p< 0.00; WC percentile categories (75th to <90th vs <75th) OR 3.16 (95% CI 2.43–4.10) p< 0.001,(≥ 90th percentile vs <75th) OR 4.08 (95% CI 2.35–7.10) p< 0.001 Hypertension: BMI categories (Overweight vs normal weight) OR 3.56 (95% CI 3.02–4.19) p< 0.001, (Obesity vs normal weight) OR 6.64 (95% CI 4.65 –9.49) p< 0.001; WC percentile categories (75th to <90th vs <75th) OR 3.29 (95% CI	Age, sex

				3.18 –4.82) p< 0.001,(≥ 90th percentile vs <75th) OR 7.41 (95% CI 4.97– 11.05) p< 0.001	
Eisenmann et al (America)	Cross sectional	130 children (68 males, 62 females) aged 3-8 years were recruited from day cares and schools in a rural midwestern community in the US and assessed for anthropometry, DEXA, and family history of heart disease. Associations between adiposity, family history of heart disease with blood pressure were explored.	Sphygmomanometer	SBP (mmHg): BMI (r= 0.26 p<0.05); WC (r= 0.35, p<0.05); SAAT (r= 0.23, p<0.05); FFM (r= 0.52, P<0.05) DBP (mmHg): BMI (r= 0.40 p<0.05); SSF (r= 0.34, p<0.05); TER(r= 0.18, p<0.05); WC (r= 0.43, p<0.05); IAAT; (r= 0.33, p<0.05); SAAT (r= 0.38, p<0.05); FFM (r= 0.27, P<0.05); FM (r= 0.40, p<0.05); %BF (r=0.30; p<0.05) Stratification by participants with family history of heart disease (NO) SBP (mmHg): BMI (r= 0.20) ; WC (r= 0.33) (YES) SBP (mmHg): BMI (r=0.30); WC (r=0.36) (NO) DBP (mmHg): BMI (r= 0.41) ; WC (r= 0.39) (YES) DBP (mmHg): BMI (r=0.41); WC (r=0.44)	Chronological age
Flores-Huerta et al (Mexico)	Cross sectional	This study included 2029 children, with age ranges 5-8 (n= 474), 9-12 (n= 643), and 13-17 (n=912). Study	Sphygmomanometer High BP= BP ≥ 90th percentile	High blood pressure: Age OR= 1.14 (95% CI 1.06- 1.22) p< 0.001, Overweight OR= 2.36 (95% 1.29- 4.33) p=0.006, Obesity OR= 3.65 (95% CI 1.57- 8.44) p= 0.003, WC ≥	Sex

		participants were assessed for anthropometry measurements and BP levels.		90TH percentile OR= 3.24 (95% CI 1.39- 7.56) p= 0.006	
Gillman et al (America)	Cross sectional	1059 mothers were recruited during gestation as part of the project viva study, a cohort study of pregnant mothers and their offspring from a multispecialty group practice in Massachusetts. Mothers were assessed for a range of maternal variables, while newborn children were assessed for BP, heart rate, and weight. The association between neonatal and maternal variables and newborn BP was explored.	Oscillometric device	SBP (mmHg): Maternal age (β= 0.8, 95% CI 0.2, 1.4), birth weight (β= 2.9, 95% CI 1.6, 4.2), 3rd trimester SBP (β= 0.9, 95% CI 0.2, 1.6), infant age when BP was measured (β= 2.4, 95% CI 1.7, 3.0) For every 5 year increase in maternal age, newborn BP increased by 0.8mmHg (95% CI 0.2, 1.4)	Race, education, financial security, household income, marital status, glucose intolerance, newborn BP measurement conditions
Goel at al (India)	Cross sectional	This cross sectional student included adolescents age 14-17 selected randomly from secondary schools located in Bhopal, India. A total of 1221 (618 boys, 603 girls) adolescents took part in	Mercury sphygmomanometer	SBP (mmHg): BMI (β= 0.901, S.E 0.05, p=0.000), DBP (β= 0.321, S.E 0.032, p=0.000), Family history of hypertension (β= 3.750, S.E 0.366, p=0.000) DBP (mmHg): Sex (β= -0.682, S.E 0.209, p=0.001), BMI (β= 0.660, S.E 0.047, p=0.000), Height (β= -5.485,	Step-wise linear regression

		the study and assessed for anthropometric characteristics, socioeconomic characteristics and BP.		S.E 1.950, p=0.005), SBP (β= 0.123, S.E 0.137, p=0.000), Family history of hypertension (β= 3.750, S.E 0.366, p=0.000), sleep disturbance (β= 1.162, S.E 0.330, p=0.003), family history (β= 1.095, S.E 0.236, p=0.000), birth weight (β= 0.243, S.E 0.024, p=0.000)	
Goharian et al (Multi-country study (Estonia and Denmark)	Prospective cohort	Data used in this study was obtained from the European youth heart study, a multi country longitudinal study conducted in children. A total of 1506 children aged 9 to 11 and 14 to 16 provided data on all the important variables including DNA samples, BP, anthropometric variables and metabolic profile. The study examined associations between fasting glucose using genetic indicators and blood pressure.	Dinamap model XL; Critikron	SBP z scores: fasting glucose {β= 0.32 (95% CI 0.20, 0.440) p<0.0001} DBP z scores: {β= 0.13 (95% CI 0.04, 0.21) p<0.0001} No significant associations were observed between genetic variants of fasting glucose and BP.	Age, age group, gender, country, insulin, total cholesterol, triglycerides, HDL, BMI, WC, soft drinks intake, fruit and vegetable consumption, cardiorespiratory fitness, birth weight, maturity, parental education, breastfed
Going et al (America)	Cross sectional	Data on 12, 279 (6222 boys, and 6057 girls) white, black and Mexican-American children were examined using NHANES 3	Auscultation device	Boys (6-11years) SBP (mmHg) (odds of being in the most adverse 20th percentile and above): 15-19.9% body fat OR= 2.66 (1.53, 4.63); 20-24.9 % body fat OR= 3.03 (1.69,	NHANES 3 versus 4, race (white, black, Mexican-American, ratio of triceps to subscapular skin fold thickness, and interaction terms for %

		(1994- 1998), and NHANES 4 (1999-2004)		5.46); 25-29.9% body fat OR= 3.88 (2.14, 7.03); ≥ 30% body fat OR= 7.77 (4.46, 13.6) Boys (12-18 years) SBP (mmHg) (odds of being in the most adverse 20th percentile and above): 10-14.9% body fat OR=1.69 (1.19, 2.40); 15-19.9% body fat OR= 2.72 (1.85, 4.01); 20-24.9 % body fat OR= 3.55 (2.35, 5.35); 25-29.9% body fat OR= 6.28 (4.17, 7.03); ≥ 30% body fat OR= 6.91 (4.58, 10.4) Girls (6-11 years) SBP (mmHg) (odds of being in the most adverse 20th percentile and above): 20-24.9% body fat OR= 1.39 (1.03, 1.89); 25-29.9% body fat OR= 1.92 (1.35, 2.72); 30-34.9% body fat OR= 2.88 (1.98, 4.20); ≥35% body fat OR= 3.14 (1.98, 4.98) Girls (12-18 years) SBP (mmHg) (odds of being in the most adverse 20th percentile and above): 25-29.9% body fat OR= 1.97 (1.46, 2.65); 30-34.9% body fat OR= 2.98 (2.15, 4.13); ≥35% body fat OR= 3.97 (2.59, 6.09)	fat with race and age

				Results for DBP were mostly inconsistent across age, gender and % body fat groups.	
He et al (America)	Cross sectional	920 African-American, Asian and Caucasian children ages 5-18 years	Mercury sphygmomanometer	SBP (mmHg): Trunk fat using DXA (t= 5.61, p=0.0001), and Skinfold measurement (t= 4.91 p= 0.0001) DBP: Trunk fat using DXA (t=3.83, p=0.0001) and skinfold measurements (t= 2.87, p=0.004) Interactions by sex for boys observed using DXA and skinfold for SBP and DBP	Total fat, sex, race, pubertal group
Hemachandra et al (America)	Prospective cohort	Participants in this study were enrolled as part of the collaborative perinatal project a multi center study that included 12 medical centres in the US. Briefly, women were enrolled at their first prenatal visit and followed up during pregnancy to delivery. The offspring of the participants were followed up for 7 years and assessed for detailed medical, social and neuropsychological factors at multiple	Manual sphygmomanometer	SBP (mmHg): Birth weight {β= 0.88 (95% CI 0.48, 1.28), p<0.001}, white race {β= 4.05 (95% CI 2.30, 5.80), p<0.001}, birth weight X race{β= -0.86 (95% CI -1.40, 0.33), p<0.002}, poverty {β= 0.54 (95% CI 0.26, 0.81), p<0.001}, maternal education {β= -0.22 (95% CI -0.27, -0.16), p<0.001}	Stepwise linear regression

		follow up periods. A total of 29,710 black and white participants made up this study. The association between maternal and perinatal factors with BP at 7 years was explored.			
Huang et al (Australia)	Cross sectional	Participants for the study were recruited as part of the West Australian pregnancy cohort. Briefly, 2804 pregnant women between 16-20 weeks were recruited from hospitals. The current study includes 1149 healthy participants (mean age 13.8 ± 0.4) using data on 14 year follow up.	Oscillometric sphygmomanometer	Boys SBP (mmHg) = Weight β= 0.20 (95% CI 0.12, 0.28) p<0.001, Height β= 0.16 (95% CI 0.03, 0.29) p=0.02, adjusted R^2 = 0.14 Girls SBP (mmHg) = Waist β= 17.07 (95% CI 8.01, 26.12) p<0.001, adjusted R^2 = 0.14	Adjusted for age, family income (annual earnings in Australian dollars $ 0 – 30 000, $ 30 001 – 60 000, $ 60 001 – 78 000, $78 001), physical activity
Huntington-Moskos et al (America)	Cross sectional	148 Caucasian adolescent ages 15-18 (88 female, 60 male) recruited from two high schools in a rural county.	Oscillometric device (Dinamap pro series 100)	SBP (mmHg): WC (t= 6.7, p<0.001), Age (0.7, p= 0.9), gender (5.5, p<0.001) and salivary cotinine (a measure of exposure to tobacco) (t= 1.9, p=0.06). These variables in combination explained 35% of SBP variance. DBP: WC (t= 5.3, p<0.001), Age (1.7, p= 0.09), gender (0.2, p= 0.8) and salivary cotinine (t= 1.9,	Step wise multiple regression used

				p=0.06). These variables in combination explained 18% of DBP variance.	
Jago et al (America)	Prospective cohort	The study analyzes pre and post data from the HEALTHY study. The HEALTHY study is a US national institute of diabetes, digestive and kidney disease cluster randomized control trial conducted using middle school children. This ample was limited to 4603 (2175 males and 2428 females). Data was collected at the 6th grade (baseline) and children were followed up to the 8the grade level	Automated blood pressure monitor	Males SBP (mmHg): Change in BMI Z score {β =2.35 (95% CI 0.6, 4.11) p<0.001} DBP (mmHg): Change in BMI Z score {β =3.15 (95% CI 0.7, 5.58) p<0.001} Females SBP (mmHg): Change in BMI Z score {β =1.57 (95% CI 0.02, 3.13) p=0.05} DBP (mmHg): Change in BMI Z score {β =2.63 (95% CI 0.37, 4.88) p=0.02}	WC z score, thence group, pubertal development (tanner staging), parental education
Jones et al (England)	Prospective cohort	Participants in this study were recruited as part of the Avon longitudinal study of parents and children established in 1990 aimed at investigating determinants of childhood health. For this study, 3230 boys and 3346 girls with data on BP at 10 years were included. The	Oscillometric device	<u>Model 1</u> (Prenatal growth) SBP (mmHg): Weight {β= -0.33 (95% CI -0.55 to -0.11) p=0.003}, Weight for height {β= 0.27 (95% CI 0.52 to 0.02) p=0.035} <u>Model 2</u> (Infant growth 0-17 month) SBP (mmHg): Weight {β= 0.90 (95% CI 0.68 to 1.12) p<0.001}, Weight for height {β= 0.41 (95% CI 0.16 to 0.66) p<0.001}, height {β= 0.82	Sex

		association between adiposity trajectories through birth and BP at 10 years was explored.		(95% CI 0.58 to 1.07) p<0.001} Model 3 (post infancy growth >17 months to 10 years) SBP (mmHg): Weight {β= 1.91 (95% CI 1.69 to 2.13) p<0.001}, Weight for height {β= 1.56 (95% CI 1.32 to 1.81) p<0.001}, height {β= 1.20 (95% CI 0.96 to 1.45) p<0.001}	
Kagura et al (South Africa)	Prospective cohort	Participants for this study were recruited as part of the Birth to twenty cohort, a longitudinal study of singletons born in Johannesburg in 1990 (n=3273). This present study includes just black participants who had not being pregnant at the time of data collection at follow up and had completed anthropometric and BP measurements at the different stages of follow up periods (n= 1937). The association between growth and BP trajectories between 5 and 18 years was explored.	Oscillometric device (OMRON M6) The BP trajectories represent mean BP based on the posterior probabilities of being assigned to a particular class. The BP trajectories were labeled as lower, middle, or upper. The lower trajectory was considered as the reference group in all regression analyses	BOYS Middle vs lower trajectory group SBP (mmHg): Birth weight Z score OR= 0.75 (95% CI 0.58, 0.96) p=0.0223 DBP (mmHg)= Relative weight gain in infancy OR= 1.43 (95% CI 1.06-1.95) p= 0.0214 Upper vs lower trajectory group SBP (mmHg): Relative weight gain in infancy OR= 4.11 (95% CI 1.25-13.51) p= 0.0202 DBP (mmHg)= Relative linear growth in infancy OR= 0.47 (95% CI 0.29- 0.76) p= 0.0021 GIRLS Middle vs lower trajectory group SBP (mmHg): Relative weight gain in infancy OR= 1.33 (95% CI 1.0,	Multinomial logistic regression of growth variables and BP trajectory classes with height as time-varying covariate and gestational age, parity, SES in infancy, and maternal age as a time-invariant covariates

				1.76) p=0.0492, Relative linear growth in infancy OR= 1.58 (95% CI 1.15, 2.17) p=0.0046 DBP (mmHg): Relative weight gain in mid- childhood OR= 1.28 (95% CI 1.02, 1.61) p=0.0317 <u>Upper vs lower trajectory group</u> SBP (mmHg): Relative weight gain in infancy OR= 1.63 (95% CI 1.08-2.46) p= 0.0211, Relative weight gain in mid-childhood OR= 1.77 (95% CI 1.22- 2.56) p= 0.0025, relative linear growth in infancy OR= 1.90 (95% CI 1.27- 2.86) p= 0.0019, relative linear growth in mid-childhood OR= 2.12 (95% CI 1.39-3.23) p= 0.0005 DBP (mmHg)= Relative weight gain in infancy OR= 2.53 (95% CI 1.14-5.57) p= 0.0219	
Katona et al (Hungary)	Cross sectional	10, 194 (5163 boys, 5031 girls) adolescents aged 15 to 18 years were recruited from 26 schools in Debrecen, Hungary and assessed for lifestyle factors, anthropometry and BP. The study explores	Oscillometric device	SBP (mmHg): BMI (β= 0.25, p<0.001) Gender(β= –0.36, p<0.001), Age (β= 0.03, p=0.001), Hypertensive mother (β= 0.02, p= 0.008) Hypertensive father (β= 0.04, p<0.001) Smoking (β= –0.07, p<0.001) Alcohol consumption (β= –0.04, p=	

		factors influencing BP in adolescents.		0.001) DBP (mmHg): BMI (0.25, p<0.001), Gender (β= –0.09, p<0.001), Age (β= 0.04, p= 0.001), Hypertensive mother (β= 0.02, p= 0.02), Hypertensive father (β= 0.03, p=0.007), Physical activity (β= –0.03, p=0.002), smoking (β= –0.05, p<0.001), Alcohol consumption (β= –0.03, p= 0.002)	
Khoury et al (Norway)	Prospective cohort	Participants for this study were children born to mothers enrolled in the CARRDIP study 6 months after birth. Briefly, the CARRDIP was a randomised controlled trial that examined the effect of a cholesterol lowering diet during pregnancy on 290 healthy Caucasian women with a range of factors and outcomes. 211 (105 intervention, 106 control) maternal-child pairs took part in the follow up study. The associations between umbilical artery pulsability index with	Oscillometric device	Model 1 SBP (mmHg): Maternal weight gain during pregnancy to week 24 {β= 0.799 (95% CI -0.042, 1.640) P=0.06}, maternal diastolic BP six months after birth {β= 0.192 (95% CI 0.043, 0.342) p=0.01}, change in pulsability index (week 24-30) (≥ -0.17 versus < -0.17){β=2.595(95%CI 0.332, 4.858) p=0.03} Model 2 SBP (mmHg): Maternal weight gain during pregnancy to week 24 {β= 0.898 (95% CI 0.057, 1.740) p=0.04}, maternal diastolic BP (weeks 17-20) (≥ -0.17 versus < -0.17){β= 0.167 (95% CI 0.018, 0.316) p=0.01}, change in pulsability index (week 24-30) {β=2.228 (95%CI -0.035, 4.491) p=0.05}	Stepwise linear regression 9criteria for inclusion included those with p<0.05 in univariate analysis).

		blood pressure in infants was examined.			
Klakk et al (Denmark)	Prospective cohort	800 children aged 7-12 years in grades 2 to 4 recruited as part of the CHAMPS study-DK who took part in whole body scan using DEXA at baseline and followed up over two years were selected for this study. Of these, only 365-438 participants had full data on BP, adiposity measures, cardiorespiratory fitness and cardio metabolic risk factors were included in the current analyses. The association between baseline adiposity metrics and cardio metabolic risk factors was explored	Oscillometric device	SBP (mmHg): Total body fat % (β= 0.20, 95% CI 0.11, 0.30, p<0.001) BMI (β= 0.16, 95% CI 0.07, 0.25, p<0.001)	Age, gender, school type, pubertal status, birth weight, parental education, cardiorespiratory fitness
Kuciene et al (Lithuania)	Case- control study	This study includes 1947 participants (962 boys, 985 girls) aged 12-15 years recruited from 29 schools in two Lithuanian district municipalities.	Oscillometric device Prehypertension was defined as an average SBP or DBP levels between ≥90th percentile and	Prehypertension/hypertension: Neck circumference (≥90th vs <90th): (OR= 3.75, 95% CI 2.86, 4.91), BMI (overweight/obesity vs normal weight): (OR= 4.24 95% CI 3.26, 5.51), WC (≥75th vs <75th): (OR= 3.97, 95% CI 2.99, 5.26), (NC ≥ 90th and normal weight vs NC <	Age, sex.

			<95th percentile; and hypertension was defined as an average SBP or DBP ≥95th percentile	90th and normal weight): (OR= 2.12 95% CI 1.43, 3.15), (NC < 90th and overweight/obesity vs NC < 90th and normal weight): (OR= 2.83 95% CI 1.98, 4.02), (NC ≥ 90th and overweight/obesity vs NC < 90th and normal weight): (OR= 7.38 95% CI 5.09, 10.70), (NC ≥ 90th and WC < 75^{th} vs NC < 90th and WC < 75^{th}): (OR= 2.56 95% CI 1.79, 3.66), (NC < 90th and WC ≥ 75^{th} vs NC < 90th and WC < 75th): (OR= 2.68 95% CI 1.82, 3.94), (NC ≥ 90th and WC ≥ 75th vs NC < 90th and WC < 75th): (OR= 7.06 95% CI 4.74, 10.51),	
Landazuri et al (Colombia)	Cross sectional	A total of 501 children and adolescents aged 8-18 years recruited from 25 schools in Quinidio, Columbia cross a sample of diverse age, gender and socioeconomic background make up the current analyses. Participants were assessed for anthropometry, serum angiotensin- converting enzyme (ACE) (a key enzyme in the renin angiotensin system), and BP. The association between	Random-zero sphygmomanometer	Girls SBP (mmHg): S-ACE (r= -0.20, p<0.001) Multivariate analyses Total sample SBP (mmHg): Age (β= 0.4, 95% CI 0.02, 0.6) p<0.001 DBP (mmHg): Age (β= 0.13, 95% CI 0.047, 0.3), gender (β= 0.026, 95% CI 0.89, 0.94), BMI (β= 0.23, 95% CI 0.08, 0.38)	

		anthropometry, sociodemographic and serum-ACE was explored.			
Le-Ha et al (Australia)	Cross sectional	Participants in this study were recruited as part of the RAINE study, a longitudinal study of a pregnancy cohort of 2900 women recruited during gestation. For this present study, data on the 17 year follow up of 1248 adolescents who completed questionnaires on social, lifestyle, anthropometry, cardiorespiratory fitness, blood measures for biochemical analyses, maternal factors and BP was utilized. The association between components of the Hypothalamic-pituitary adrenal axis and cardiovascular risk factors, including BP was examined.	Oscillometric device	Model 1 SBP (mmHg):Total cortisol {β= 0.0037, (95% CI 0.0009, 0.0066), p=0.011}	Sex, BMI, oral contraceptive use, birth weight, gestational age, socio-behavioural factors
Leung et al (China)	Cross sectional	6193 students (3074 boys and 3119 girls)	Oscillometric device (Accutorr plus monitor).	Hypertension: Boys {OR= 1.934 (95%CI 1.189, 3.145) P=0.008}, WC	Age, BMI, parental hypertension, sleep

		were recruited from secondary schools in Hong Kong randomly selected from each of the 18 Hong Kong districts. Participants were assessed for anthropometric characteristics, physical activity and BP measures. The association between anthropometry, physical activity with hypertension was explored.	Hypertension defined as SBP/DBP at the 95th percentile on 3 separate measurements.	≥85th percentile {OR= 2.378 (95%CI 1.134, 4.987) P=0.022}, physical activities ≥ twice a week {OR= 0.282 (95%CI 0.113, 0.706) P=0.007}	duration.
Lim et al (Singapore)	Prospective cohort	Participants for this study were part of the Growing Up in Singapore Towards Healthy Outcomes Study (GUSTO) study, a prospective cohort of mother-children pairs. For the GUSTO study, 1162 pregnant women less than 14 weeks of gestation were recruited from tertiary hospitals in Singapore. This current study includes 567 mother children pairs followed up after 3 years with	Oscillometric device	Offspring Peripheral SBP (mmHG): (women with normotensive pregnancies n=537) maternal central SBP (β= 0.10 (95% CI 0.00, 0.19) p=0.04) Offspring Pulse pressure: (All women n=567) maternal central pulse pressure (β= 0.10 (95% CI 0.01, 0.18) p=0.03	Maternal age, education level, parity, smoking status, alcohol consumption, physical activity during pregnancy, pre-pregnancy BMI, offspring sex, ethnicity, BMI, and height at 3 years of age

		complete blood pressure information.			
Lurbe et al (Spain)	Cross sectional	630 healthy children aged 4 to 18 years born at term to normotensive mothers were recruited from pediatric clinics in Spain. Data on gestational age and birth weight were obtained from records, while BP was measured using 24-hour ambulatory blood pressure measurement. The association between birth weight and BP was explored.	Ambulatory blood pressure monitor	24- hour SBP: birth weight (r= -0.13, p=0.001) 24 hour DBP: birth weight (r= -0.12, p=0.003) <u>Multiple linear regression</u> 24- hour SBP: ↑Current weight (p<0.001), ↓birth weight (P< 0.002) R^2= 0.185	Age, gender, current weight and height
Mbolla et al (Congo)	Cross sectional	603 children aged 5 -18 years were selected from a population of five schools in Brazzaville, chosen by cluster sampling. Study participants were assessed for a range of social, lifestyle and physiological measures.	Auscultatory method Hypertension: Defined as BP at the 95th percentile. Prehypertension: BP at the 85th to 95th percentile.	Prehypertension: secondary school (yes/no) OR= 2.466 (95% CI 1.57-3.87) p=0.0001, Migration (yes/no) OR= 1.826 (95% CI 1.01-3.28) p=0.044, Obesity (yes/no) OR= 3.391 (95% CI 1.45- 7.89) p=0.0046, Overweight (yes/no) OR= 2.361(95% CI 1.2- 4.61) p=0.011 Hypertension: Obesity (yes/no) OR= 86.81 (95% CI 9.21- 818) p=0.0001, Overweight (yes/no) OR= 27.2 (95% CI 5.14- 144) p=0.0001	Socioeconomic level, private school Socioeconomic level,

					private school, migration, secondary school, orphans
Mirzaei et al (Australia)	Prospective cohort	Participants in this study were recruited from primary schools within Sydney, Australia. A total of 1230 children aged 8-10 were recruited at baseline and followed up for 3 years. Participants were assessed for anthropometric, parental characteristics and BP. The association between anthropometric characteristics and BP at baseline and follow-up was assessed.	Oscillometric device	<u>Boys</u> SBP (mmHg): Change in BMI (r=0.43 p<0.001), change in waist circumference (r=0.18, p<0.001), current weight (r=0.47, p<0.001) DBP (mmHg): Change in BMI (r=0.26 p<0.001), change in waist circumference (r=0.16, p<0.001), current weight (r=0.28, p<0.001) <u>Baseline analysis</u> SBP: Birth weight (β= -1.47, p<0. 01), current weight (β= 0.60, p<0.0001), BMI (1.16, p<0.0001), Waist circumference (β= 0.38, p<0.0001), waist to height ratio (β= 0.51, p<0.0001) <u>Girls</u> SBP (mmHg): Change in BMI (r=0.40 p<0.001), change in waist circumference (r=0.13, p<0.001), current weight (r=0.45, p<0.001) DBP (mmHg): Change in BMI (r=0.26 p<0.001), change in waist circumference (r=0.11, p<0.001), current weight (r=0.28, p<0.001)	Age, height and socioeconomic status

				<u>Baseline analysis</u> SBP: Birth weight (β= -2.32, p<0.01), current weight (β= 0.56, p<0.0001), BMI (1.06, p<0.0001), Waist circumference (β= 0.39, p<0.0001), waist to height ratio (β= 0.52, p<0.0001)	Age, height and socioeconomic status
Moore et al (America)	Cross sectional	1829 multi ethnic children aged 5-17 years old were recruited to participate in this study from public school districts in Oklahoma city. Participants were screened for BP, demographic and anthropometric characteristics. The relationship between demographic factors and anthropometric	Mercury sphygmomanometer Normal BP measurements <the 90th Percentile, Hypertensive BP measurements ≥the 95th percentile	<u>Boys</u> Hypertensive vs normotensive: BMI (Obese vs Normal) OR= 4.33 (95% CI 2.69, 6.96), 12-17 years old vs 5-11 OR=6.72 (4.35, 10.37) <u>Girls</u> Hypertensive vs normotensive: BMI (Obese vs Normal) OR= 4.01 (95% CI 2.51, 6.41), 12-17 years old vs 5-11 OR= 1.83 (95% CI 1.21, 2.77)	Race, BMI/age group

		characteristics with BP was investigated.			
Moser et al (Brazil)	Cross sectional	1441 children (655 boys, 786 girls) aged 10-16 years were recruited randomly by systematic sampling from five regions in Brazil. Participants were assessed for socioeconomic status, anthropometric characteristics and BP. The association between anthropometric measures and BP was explored.	Mercury column sphygmomanometer High blood pressure was characterized by the values of systolic an/or diastolic blood pressure greater than or equal to the 90th percentile or to 120 mmHg and/or 80 mmHg	High BP: BMI (normal weight vs overweight) (OR= 2.9, 95% CI 1.9, 4.5), $p<0.01$, Triceps skinfold (<90 degrees vs ≥90 degrees) (OR= 1.9, 95% CI 1.3, 3.10 $p<0.05$	Sexual maturation, socioeconomic status
Mu et al (China)	Prospective cohort	Participants for this study were recruited as part of the Hanzhong children hypertension study. At baseline, 4916 schoolchildren ages 5-6 years old were recruited and assessed for a range of factors. A total of 310 followed up after 10 years had data on baseline sodium-lithium (Na-Li) counter transport rate and blood pressure at follow	Mercury sphygmomanometer	High SBP (mmHg): Na-Li CT (β= 0.0201, $p<0.05$), BP (β= 0.0853, $p<0.01$), BMI (β = 0.0805, $p<0.05$), family history of hypertension (yes or no) (β= 0.4087, $p<0.05$) High DBP (mmHg): Na-Li CT (β= 0.0192, $p<0.05$), BP (β= 0.0804, $p<0.05$), BMI (β = 0.0796, $p<0.05$), family history of hypertension (yes or no) (β= 0.4283, $p<0.05$)	Age, gender, pulse rate

		up.			
Munthali et al (South Africa)	Prospective cohort	Participants in this study were recruited as part of the birth to twenty cohort, an ongoing longitudinal study of about 3273 children recruited from Soweto, South Africa. The current study included black participants (n=1824) with weight and height data available for at least two time points between 5 and 18 years. Associations between adiposity trajectories and BP in adolescence were explored.	Oscillometric device Prehypertension was defined as SBP readings from 120 to 139 mm Hg or a DBP from 80 to 89 mm Hg while hypertensive was defined as SBP readings equal or greater than 140 mm Hg or DBP readings equal or greater than 90 mm Hg. Due to small sample size the prevalence of hypertension, prehypertension and hypertension were combined and defined as elevated blood pressure	<u>Boys</u> SBP (mmHg): Early onset overweight to obese vs normal weight (OR=13.45, 95% CI 6.82-20.07, p<0.01), height at 18 years (OR= 0.27, 95% CI 0.15-0.38, p<0.01) DBP (mmHg): Early onset overweight to obese vs normal weight (OR= 5.74, 95% CI 0.39-11.10, p<0.01) Elevated blood pressure at 18 years (normal vs reference): Height(cm) at 18 years {OR= 1.02 (95% CI 1.00 to 1.05, p<0.05} <u>Girls</u> SBP(mmHg): early onset obese to overweight vs Normal weight (OR=4.18, 95% CI 1.03-7.33, p<0.01), early onset obese to morbidly obese vs normal weight (OR=6.08, 95% CI 2.93-9.23, p<0.01), height at 18 years (OR= 0.22, 95% CI 0.11-0.34, p<0.01), DBP (mmHg): early onset obese to overweight vs Normal weight (OR=4.44, 95% CI 1.65-7.22, p<0.01), early onset obese to morbidly obese vs normal weight	Birth weight, height at 18 years

				(OR=4.28, 95% CI 1.50- 7.07, p<0.01) Elevated blood pressure at 18 years (normal vs reference): Early Onset Obese to Overweight {OR= 1.95 (95% CI= 1.01 to 3.77, p<0.05}; Early Onset Obese to Morbidity Obese {OR= 2.18 (95% CI= 1.31 to 4.20, p<0.05}	
Musa et al (Nigeria)	Cross sectional	3243 children and adolescents aged 9-15 years old were recruited from 21 schools in three districts in Northcentral Nigeria. Participants were assessed for measures of cardiorespiratory fitness, anthropometry and BP. The association between cardiorespiratory fitness, and anthropometry with BP was investigated.	Oscillometric device	Boys Children (age 9-11 years) SBP (mmHg): Fatness (β= 0.167, p=0.0005), R^2= 0.031 DBP (mmHg): fatness (β= 0.127, p=0.005), R^2= 0.017 Adolescents (age 12-15 years) SBP (mmHg): Fatness (β= 0.187, p=0.0005), R^2= 0.035 DBP (mmHg): Fatness(β= 0.017, p=0.005), R^2= 0.005 Girls Children (age 9-11 years) SBP (mmHg): Fatness (β= 0.155, p=0.0005), R^2= 0.024 Adolescents (age 12-15 years) SBP (mmHg): Fitness (β= -0.058, p=0.043), R^2= 0.024, Fatness (β=	Age, sex

				0.161, p=0.0005), R^2= 0.028 DBP (mmHg): Fitness (β= 0.067, p=0.021), R^2= 0.024, Fatness (β= 0.120, p=0.0005), R^2= 0.020 Fitness measured using the progressive aerobic cardiovascular endurance run (PACER) Fatness measured using BMI	
Na young Kim et al (South Korea)	Cross sectional	565 adolescents age 12-16 years old were enrolled in a cross sectional study from a school in South Korea. Study participants were assessed for anthropometry (BMI, %BF, WC, and height), metabolic risk factors, hemodynamic factors and BP.	Oscillometric device The 90th percentile for SBP and DBP were defined as "high SBP" and "high DBP,"	<u>Boys</u> Model 1 High SBP: BMI >85th percentile (OR=3.12, 95% CI 1.81, 6.43) High DBP: BMI >85th percentile (OR=3.19, 95% CI 1.84, 6.58) <u>Girls</u> Model 1 High SBP: BMI >85th percentile (OR=5.44, 95% CI 1.55, 18.82) High DBP: BMI >85th percentile (OR=3.41, 95% CI 1.63, 8.88) No associations observed for high waist to height ratio (>90th percentile) or high body fat percentage (>90th percentile) after full adjustment.	Age, height, lipid panel, glucose, c reactive protein, waist-to height ratio/%body fat/BMI
Narang et al (Canada)	Cross sectional study	4104 adolescents recruited as part of a program called the	Oscillometric device	Hypertension: sleep disturbance score (tertile 3 vs 1) OR= 1.443 (95% CI 1.017, 2.048) p=0.05	Nutrition, physical activity, sex, family history of premature

		Healthy heart school program in the Niagara region of Ontario were assessed for measurements on sleep characteristics. The association between sleep variables and blood pressure was explored.	Hypertension defined as ≥ 99th percentile)		cardiovascular disease, adiposity
Nayoung Kim et al (America)	Prospective cohort	847 children in the 9th - 11th grade were selected as part of the HEROES initiative. The HEROES initiative is a multicomponent school based obesity prevention aimed at improving systolic and diastolic BP over 18 months in high school children. This study examines the effectiveness of the HEROES initiative in improving blood pressure.	Oscillometric method	SBP (mmHg): Linear time {β = -4.15 (-6.54, -1.77) p= 0.0006}; Quadratic time {β =2.30 (0.63, 3.97) p= 0.0071}; BMI percentiles {β = 0.75 (0.61, 0.89) p< 0.0001}; Male (vs female) {β =5.09 (3.67, 6.50) p< 0.0001}; television viewing hours/day {β =0.37 (0.02, 0.71) p= 0.036} DBP (mmHg): Linear time {β = -4.05 (-5.92, -2.19) p< 0.0001}; Quadratic time {β =2.35 (1.03, 3.66) p= 0.0005}; BMI percentiles {β = 0.34 (0.25, 0.44) p< 0.0001}; television viewing hours/day {β =0.39 (0.14, 0.64) p= 0.0019}	Sequential multivariate generalized estimating equation models used. Full list of variables in the model includes: Linear time, quadratic time, BMI percentiles, sex, television viewing hours/day, moderate-intensity physical activity, vigorous-intensity physical activity, eating French fries two times or more per day, usually skipping breakfast, portion sizes
Nowson et al (Australia)	Cross sectional	Participants in this study were recruited as part of an ongoing longitudinal study	Oscillometric device	SBP (mmHg): BMI (β= 0.63, SE 0.18, p<0.001)	Age

		conducted in female twins in Australia. For this study cross sectional data on BP and anthropometric variable was used. The association between birth weight and BP was explored.			
Nur et al (Turkey)	Cross sectional	1041 participants (593 male, 427 females) were recruited from six high schools in Turkey selected through a multi stage sampling. Study participants were assessed for a range of social, anthropometry and CVD risk factors including hypertension. Associations between variables collected and hypertension was explored.	Auscultatory method Students whose repeated systolic or diastolic blood pressures were higher than the 95th percentile were considered to be hypertensive	Hypertension: BMI {β= 0.50, (95% CI 0.62, 3.43) p=0.00}	Age, gender, smoking, family history of diabetes, family history of hypertension, urinary tract infection.
Odunaiya et al (Nigeria)	Cross sectional	1079 participants aged 15-18 years were recruited from 22 schools within a local education authority of Oyo state, Nigeria. The participants were then assessed for lifestyle CVD risk factors, anthropometry and BP.	Automated sphygmomanometer Pre-hypertension Systolic = 80-89mm/Hg Diastolic = 120–139mm/Hg	Males Systolic pre-hypertension: Age (17 vs 15) (OR= 2.4, 95% CI 1.3-4.2), (18 vs 15) (OR= 3.9, 95% CI 2.3, 6.9), BMI (high) (OR= 4.2, 95% CI 2.4, 7.3), alcohol (any) (OR= 1.6, 95% CI 1.0, 2.4) Females BMI (high): (OR=2.4, 95% CI 1.5,	Multivariate model: tobacco, physical activity, cholesterol, vegetables, salt and fruits.

		Risk factors for pre-hypertension was explored in this population.		3.9)	
Peach et al (America)	Cross sectional	Participants from this study are drawn from the study of early childcare and youth development, a longitudinal study designed to examine relationships between childcare experiences, child development and well-being. At the time of recruitment (1991), 1364 families were interviewed 1 month after the birth of a child, and data on children developmental experiences were collected in 5 phases up until 2007. The present study includes data collected at the third phase of data collection (2000-2004) with a few data collected at baseline (gender, ethnicity). The study examines relationship between sleep characteristics	Auscultatory device Hypertension defined as BP at the 95th percentile for age, gender and height	Hypertension: School night sleep (indirect) β= -0.06 (S.E 0.03) $p<0.05$, weekend sleep (indirect) β= -0.04 (S.E 0.01) $p<0.01$, sleepiness (indirect) β= 0.26 (S.E 0.07) $p<0.01$, BMI (direct) β= 0.09 (S.E 0.01) $p<0.001$ R^2 = 0.18 *Indirect effects refers to the contributory mediation effects of BMI.	Age, gender, ethnicity, income, unhealthy eating habits, depression, attention /behaviour problems, physical activity and pubertal development.

		and BP.			
Polderman et al (Brazil)	Cross sectional	1002 adolescents (442 boys, 560 girls) were recruited from 30 private and public schools within districts in Arcaju, Brazil. Participants were assessed for demographic factors, anthropometry and BP.	Oscillometric device	Boys SBP (mmHg): Overweight vs Normal (β= 4.69, 95% CI 0.69, 8.70), Obese vs Normal (β= 16.21, 95% CI 8.78, 23.63) DBP (mmHg): Obese vs Normal (β= 6.65, 95% CI 0.80, 12.50) Girls SBP (mmHg): Overweight vs Normal (β= 10.38, 95% CI 7.92, 12.85), Obese vs Normal (β= 10.68, 95% CI 5.07, 16.28) DBP (mmHg): Overweight vs Normal (β= 5.75, 95% CI 3.99, 7.51), Obese vs Normal (β= 5.02, 95% CI 1.88, 8.16)	Age, type of school, physical activity
Quieroz et al (Brazil)	Cross sectional	750 children aged 6 to 9 years were recruited from public elementary schools in the city of Joao Pessoa, Brazil and assessed for social characteristics, anthropometry and BP. The association between anthropometric factors and BP was investigated.	Aneroid sphygmomanometer High blood pressure defined as individuals with mean SBP/DBP ≥95th percentile.	Model 1 High BP: weight (OR= 1.05, 95%CI 1.03-1.08) Model 2 High BP: BMI (OR= 1.17, 95%CI 1.09-1.25) Model 2 High BP: Abdominal circumference (OR= 1.06, 95%CI 1.03-1.09)	Age, sex
Ramos-Arellano	Cross	252 children (124 girls	Aneroid	Hypertension: Suprailiac skinfold,	Age, sex and BMI

et al (Mexico)	sectional	and 128 boys) aged 6 to 13 years were recruited from schools and activity centre in Gurrero, Mexico and assessed for anthropometry variables and BP. The association between anthropometric variables and BP was explored.	sphygmomanometer Hypertension was defined as the average of the 2 measurements where the systolic BP (SBP) or DBP is in the 95th percentile or higher for age and sex	third tertile (>17.5 mm) (OR=11.8, p= 0.023, 95% CI 1.40, 99.7), Triceps skinfold, third tertile (>16 mm) (OR= 6.02, p= 0.034, 95% CI 1.14, 31.75), Biceps skinfold, third tertile (>15 mm) (OR= 4.71, p= 0.038, 95% CI 1.09, 20.34)	
Relton et al (England)	Cross sectional	Of 1129 children recruited from 26 schools in Newcastle, 483 children (274 girls, 209 boys) ages 6 to 16 years had completed all measurements and were included in the study. Data on gestational age was obtained from birth records.	TM-2421 (Ambulatory blood pressure measurement device)	24 hr SBP (mmHg): gestational age (r= -0.63, 95% CI -1.21, -0.04) p= 0.036	Birth weight (z scores), and weight at study enrolment
Ribeiro et al (Brazil)	Cross sectional	1403 children aged 6 to 18 years were recruited from 521 public and private schools in Belo Hoizonte, Brazil, and assessed for a range of anthropometry, and BP. The association between obesity, and blood pressure was	Mercury Sphygmomanometer	SBP (mmHg) (>90th percentile)= Body-mass index (>85th) vs.(<85th) OR= 3.6 (95% CI 2.2, 5.8); DBP (mmHg) (>90th percentile): Body-mass index (>85th) vs.(<85th) OR= 2.7 (95% CI 1.9, 4.0)	Age, race, socioeconomic standing, type of school, measures of subcutaneous adiposity

		explored.			
Savva et al (Cyprus)	Cross sectional	1987 boys and girls ages 10-14 years old (mean age 11.4± 0.4) from both urban and rural areas in Cyprus	Mercury sphygmomanometer	SBP (mmHg): WC (β= 0.69, SE= 0.70, p<0.001, r^2=0.142), WHtR (β= -119.66, SE= 10.94, p<0.001, r^2=0.035), BMI (β= 1.09, SE= 0.16, p<0.001, r^2=0.018), Age (β= -1.20, SE= 0.55, p=0.028, r^2=0.002) DBP (mmHg): WC (β= 0.40, SE= 0.06, p<0.001, r^2=0.098), WHtR (β= -54.02, SE= 9.23, p<0.001, r^2=0.011), BMI (β= 0.50, SE= 0.14, p<0.001, r^2=0.006), Age (β= -3.67, SE= 0.46, p<0.001, r^2=0.020)	Step wise multiple regression used
Sesso and Franco (Brazil)	Cross sectional	64 Brazilian children aged 8-13 years born appropriate for gestational age at ≥ 37 weeks with birth weight ≥3.0kg and those born small for gestational age with birth weight ≤2.5 kg were included in this current analysis. Participants were assessed for demographic, anthropometric and clinical characteristics including plasma level of metalloproteinase, insulin, glucose and BP. the association between birth weight,	Oscillometric device	SBP (mmHg): matrix metalloproteinase-2 (MMP-2) (β=0.026, SE= 0.026, p=0.02), R^2= 8%	Stepwise regression

		endothelium function and biochemical findings with BP was explored.			
Sesso et al (Brazil)	Case-control study	A total of 172 children (91 malnourished, 20 recovering from malnutrition, and 61 non-malnourished controls) aged 2-7 years were recruited randomly from shantytowns in Sao-Paulo. Participants' medical history, socio-demographic characteristics, physical measures and BP was taken.	Mercury sphygmomanometer	SBP (mmHg): Weight (β= 0.66, SE= 0.26, $p<0.05$) DBP (mmHg): Malnourished vs control (β= 3.49, SE= 1.13, $p<0.01$), Recovered vs control (β= 4.65, SE= 1.67, $p<0.05$)	Age, race, sex, height, birth weight
Sharp et al (America)	Cross sectional study	115 Hispanic and Caucasian adolescent s were recruited across a range of BMI from two public schools in Denver, US. Participants were assessed for anthropometric characteristics, metabolic profile and BP. Associations between anthropometric characteristic and BP	Random zero sphygmomanometer	<u>Pearson's partial correlations</u> SBP (mmHg) = Weight (r= 0.33, p= 0.002); BMI (r= 0.31, p= 0.004); WC (r=0.23, p=0.03) DBP (mmHg)= weight (r= 0.37, p= 0.0004); BMI (r= 0.34, p= 0.001); % body fat (r= 0.30, p= 0.005); waist (r= 0.29, p= 0.007) <u>Multivariate model</u> SBP (mmHg): Weight p= 0.003, WC p=0.05; adjusted R^2= 0.19 DBP (mmHg)= Weight p= 0.0004);	Gender, ethnicity

		was explored.		adjusted R^2= 0.17	Gender, ethnicity, BMI, %body fat, gender x ethnicity
Shirasawa et al (Japan)	Cross sectional	Data was obtained from 2420 elementary school fourth graders (age 9-10 years) and first year junior high students (age 12-13 years) as part of a community health service health check-ups to prevent childhood lifestyle related diseases from 2006 to 2008 in the town of Ina, Saitama Prefecture. A total of 2385 (1227 boys and 1158 girls) were analyzed for this study.	Mercury manometer Hypertension (HT) and high-normal blood pressure (HNBP) were defined as follows. In fourth graders, an SBP ≥135 mm Hg or DBP ≥80 mm Hg was defined as HT. In seventh graders, an SBP ≥140 mm Hg or DBP ≥85 mm Hg was defined as HT in boys, while an SBP ≥135 mm Hg or DBP ≥80 mm Hg was defined as HT in girls. A BP between normal BP (NBP) and HT was regarded as HNBP (fourth graders: 125 ≤ SBP < 135 or 70 ≤ DBP < 80, seventh-grade boys: 130 ≤ SBP < 140 or 70 ≤ DBP < 85, seventh-grade girls: 125 ≤ SBP < 135 or 70 ≤	Boys Fourth graders (age 9-10 years) High blood pressure: BMI at the 85th -94th percentile (compared to BMI at the 50th percentile) OR= 3.43 (1.73-6.82); BMI ≥ 95th percentile (compared to BMI at the 50th percentile) OR= 6.30 (2.81- 14.12) Seventh graders: (age 12-13 years) High blood pressure: BMI at the 85th to 94th percentile (compared to BMI at the 50th percentile) OR= 3.00 (1.38-6.54); BMI ≥ 95th percentile (compared to BMI at the 50th percentile) OR= 6.32 (2.59- 15.45) Girls Fourth graders (age 9-10 years) High blood pressure: BMI at the 85th to 94th percentile (compared to BMI at the 50th percentile) OR= 1.95 (0.92- 4.13); BMI ≥ 95th percentile (compared to BMI at the 50th percentile) OR= 13.32 (5.95- 29.84) Seventh graders: (age 12-13 years)	Family history of hypertension

			DBP < 80). Children with either HNBP or HT were considered to have high blood pressure for this analysis.	High blood pressure: BMI at the 85th to 94th percentile (compared to BMI at the 50th percentile) OR= 2.27 (0.94-5.53); BMI ≥ 95th percentile (compared to BMI at the 50th percentile) OR= 7.83 (3.12-19.63)	
Taal et al (Netherlands)	Prospective cohort	This study uses data from the Generation R study (n= 1034)- a population based prospective cohort study from fetal life into young adulthood- with median age 6 years (5.8-6.7 years) to evaluate the role of common genetic variants in influencing blood pressure in children.	Random zero sphygmomanometer	Baseline model SBP (mmHg): BMI + Sex + Age (explained 5.2% variance) Model 2 SBP (mmHg): genetic risk score based on single nucleotide polymorphisms with a $P_{discovery}$ (a set of common variants used to calculate a genetic score of all SNPs achieving a certain significance threshold) of <0.3- explained an additional 0.8% of the variance in SBP , p= 0.004 DBP (mmHg): BMI+ Sex + Age (explained 1.4% variance) Model 2 DBP: genetic risk score based on single nucleotide polymorphisms	BMI, Sex, age

				with a $P_{discovery}$ of 0.3 explained 1.4% variance of DBP, p<0.001	BMI, Sex, age
Taine et al (France)	Prospective cohort	Participants for this study were recruited as part of the EDEN cohort, a birth cohort that enrolled 2002 pregnant women before 24 weeks of gestation and followed 1907 of the recruited participants through birth. .this current study includes 1119 children who completed 5 year follow up for blood pressure measurements. The association between birth weight and blood pressure was explored	Oscillometric device	SBP: Birth weight Z score (β= -0.54, SE =0.21 p= 0.01)	Sex, age, height, BMI, maternal pre-pregnancy BMI, maternal education, smoking, history of hypertension, gestational age
Thiering et al (Germany)	Prospective cohort	Study included a prospective cohort of 3097 recruited as healthy neonates with a birth weight over 2500g, and followed up until the age of 10. The study included 1127	Automatic monitor	SBP (mmHg): 2 SD increase in peak weight velocity{β =2.13 (0.51, 3.74) p= 0.01} 2 SD increase in peak height velocity {β =2.94 (1.34, 4.54) p< 0.001}	Sex, study centre, parental education, maternal age, maternal height, weight before pregnancy, smoking during pregnancy, gestational age at birth, paternal height and

		children who completed all of the clinical examinations and had valid assessments at 10 years of age.		DBP (mmHg): 2 SD increase in peak weight velocity {β= 1.91 (0.52, 3.30) p = 0.007)	weight, parental diabetes, and hypertension, birth weight and breast feeding, BMI at age 10 years
Vlajinac et al (Serbia)	Cross sectional	This study included 1651 participants (809 boys, and 842 girls) aged 7-14 years recruited from primary schools in six urban communities in Belgrade. Participants were assessed for a range of anthropometric variables and BP	Mercury sphygmomanometer Hypertension defined as systolic/diastolic BP at the 95th percentile	<u>Boys</u> SBP (mmHg): Height (β= 0.09, 95% CI 0.02-0.17), BMI (β= 0.30, 95% CI 0.23-0.37) DBP (mmHg): BMI (β= 0.17, 95% CI 0.08-0.27), Subscapular skinfold (β= 0.13, 95% CI 0.03-0.22) Hypertension (SBP): Age (OR= 0.8, 95% CI 0.7-0.10), BMI (OR= 1.3, 95% CI 1.2-1.4) Hypertension (DBP): Age (OR= 0.9, 95% CI 0.7-0.10), BMI (OR= 1.3, 95% CI 1.2-1.4) <u>Girls</u> SBP (mmHg): Height (β= 0.09, 95% CI 0.02-0.16), BMI (β= 0.19, 95% CI 0.11-0.28), Suprailiac skinfold (β= 0.15, 95% CI 0.06-0.23) DBP (mmHg): BMI (β= 0.10, 95% CI 0.11-0.19), Subscapular skinfold (β= 0.11, 95% CI 0.04-0.22), Suprailiac skinfold (β= 0.14, 95% CI 0.04-0.25) Hypertension (SBP): Suprailiac	

				skinfold (OR= 1.1, 95% CI 1.1-1.2) Hypertension (DBP): Suprailiac skinfold (OR= 1.1, 95% CI 1.1-1.2)	
Vohr et al (America)	Cohort study	Participants in this study were recruited from a cohort of low birth weight infants who participated in a prospective randomized trial of low dose indomethacin to prevent interventricular hemorrhage. This current study consists of 296 of the preterm survivors at 16 years and 95 age, gender and race matched term controls recruited at age 8. Participants were assessed for growth assessments at different ages. BP was also assessed at age 16 years.	Oscillometric device	<u>Total cohort</u> SBP (mmHg): Male (β= 5.10, p= 0.001), BMI (β= 0.60, p=0.001), preterm (β= 5.06, p=0.002) R^2= 14.8 DBP (mmHg): Male (β= -1.7, p= 0.035), BMI (β= 0.22, p=0.002), preterm (β= 2.09, p=0.027) R^2= 4.7 <u>Preterm subjects</u> SBP (mmHg): weight gain velocity 0-36m (β= 8.54, p=0.001), pre-eclampsia (β= 5.67, p=0.02), male (β= 5.09, p=0.001), non-white (β=3.77, p=0.04)	Age, height
Walker et al (Jamaica)	Prospective cohort	Participants in this study were recruited as part of an ongoing longitudinal study in Jamaican children. Briefly, 17 stunted children, and 32 non-	Mercury sphygmomanometer	SBP (mmHg): Birth weight (β= -1.32, 95% CI -2.21, -0.42), weight at 11-12 years (β= 5.22, 95% CI 4.05, 6.39), stunted/ non-stunted x weight at 11-12 years (β= -2.61, 95% CI -5.13, -0.10) R^2= 0.33	Sex, age

		stunted children aged 9-24 months were recruited through an house to house survey and participated in a two year intervention study. For years after the intervention (age 7-8 years), the participants were located, an additional group of 175 non stunted children identified through the initial survey were recruited into the study. The current study includes 112 stunted and 189 non stunted children. The relationship between growth and BP at 11-12 years was investigated.		DBP (mmHg): weight at 11-12 years (β= 4.18, 95% CI 2.31, 6.05), stunted/ non-stunted x weight at 11-12 years (β= -6.28, 95% CI -10.32, -2.23) R^2= 0.13	
Wang et al (China)	Cross sectional	2500 children (1330 boys, 1170 girls) aged 6 to 18 years recruited as part of a population based cohort of twin pairs in China and assessed for BP and adiposity measures. Participant with missing data for DEXA, BP and BMI were excluded for	Mercury-gravity manometer	<u>Boys (6-11 years old)</u> SBP (mmHg): BMI (β= 0.98, SE= 0.24, p<0.0001), total body fat (β= 0.85, SE= 0.41, p<0.04), % body fat (β= 0.28, SE= 0.12, p=0.02), % trunk fat (β= 0.77, SE= 0.36, p<0.03), fat mass index (β= 1.71, SE= 0.67, p<0.001), lean mass index (β= 1.00, SE= 0.31, p<0.001) DBP (mmHg): BMI (β= 0.87, SE=	Age, height, education years and occupation (12-18 year old group)

		the purposes of this analysis. The study explores relationship between adiposity measures and BP in adolescents.		0.20, p<0.0001), total body fat (β= 0.74, SE= 0.33, p=0.03), % body fat (β= 0.25, SE= 0.09, p= 0.004), trunk fat (β= 2.00, SE= 0.99, p=0.04), % trunk fat (β= 0.73, SE= 0.24, p= 0.003), fat mass index (β= 1.49, SE= 0.52, p= 0.004), lean mass index (β= 0.90, SE= 0.25, p= 0.0003) <u>Girls (6-11 years old)</u> SBP (mmHg): BMI (β= 1.33, SE= 0.27, p<0.001), total body fat (β= 1.23, SE= 0.35, p<0.001), % body fat (β= 0.27, SE= 0.10, p= 0.006), trunk fat (β= 2.37, SE= 0.84, p=0.005), % trunk fat (β= 0.50, SE= 0.23, p=0.003), fat mass index (β= 2.04, SE= 0.58, p<0.001), lean mass index (β= 1.23, SE= 0.32, p<0.001) <u>(Boys 12-18 years old)</u> SBP (mmHg): BMI (β= 1.46, SE= 0.25, p<0.0001), total body fat (β= 1.08, SE= 0.31, p= 0.0004), % body fat (β= 0.41, SE= 0.14, p= 0.003), trunk fat (β= 2.26, SE= 0.69, p=0.001), % trunk fat (β= 1.05, SE= 0.32, p= 0.001), fat mass index (β= 2.37, SE= 0.67, p= 0.0004), lean mass index (β= 1.61, SE= 0.33, p<0.0001)	

				Girls (12-18 years old) SBP (mmHg): BMI (β= 1.16, SE= 0.20, p<0.001), total body fat (β= 0.54, SE= 0.15, p<0.001), % body fat (β= 0.26, SE= 0.08, p= 0.002), trunk fat (β= 1.11, SE= 0.29, p<0.001), % trunk fat (β= 0.59, SE= 0.16, p<0.001), fat mass index (β= 1.26, SE= 0.33, p<0.001), lean mass index (β= 1.71, SE= 0.34, p<0.001)	
Watts et al (Australia)	Cross sectional	119 children ages 6-13 years recruited from a paediatric hospital and schools within the same area. The study sample included 70 healthy weight, 50 overweight, and 28 obese children	Oscillometric method (Critikon Dinamap)	SBP (mmHg): WC (β = 0.29, 95% CI 0.05-0.52) Children with WC ≥ 90th percentile also had significantly average SBP than those with WC < 90th percentile.	BMI Z score
Wells et al (Brazil)	Prospective cohort	453 (143 first born and 310 later born) participants from the 1993 Pelotas birth cohort who completed full follow up into adolescence were selected. This study explores the association between birth order, birth size, post-natal growth rate	Digital wrist blood pressure monitor	SBP (mmHg): Birth order (firstborn children compared to non-first born reference group) β= 2.9 (95%CI 0.4, 4.7) p=0.02 DBP (mmHg): Birth order (firstborn children compared to non-first born reference group) β= 2.1 (95%CI 0.7, 3.6) p=0.01	Maternal age, maternal height, maternal BMI, smoking during pregnancy, family income and sex

		on blood pressure in adolescence.			
Wells et al (Brazil)	Cross sectional	Study participants were enrolled in a Brazilian birth cohort study that recruited mothers of all hospital born children and their offspring, In total, 5265 participants were recruited into the study at baseline and followed up till the age of 10-12 years old. This study include cross sectional data of all 4452 children who completed follow up measures. The association between sleep duration, body fatness and TV viewing with childhood BP was assessed.	Oscillometric device	Model 1 SBP (mmHg): sleep duration (β= -0.31 SE 0.14, p=0.03) Model 2 SBP (mmHg): television viewing (β= 0.35 SE 0.10, p<0.001) DBP (mmHg): television viewing (β= 0.25 SE 0.08, p= 0.001)	Maternal education, family social status, sex, birth weight, birth length, smoking and alcohol consumption in pregnancy, maternal BMI and hours of physical activity
Wicklow et al (Canada)	Prospective cohort	Participants in this study were recruited as part of the SAGE birth cohort in Manitoba, Canada. For this study, 438 children followed between age 7 and 13, and assessed for a range of anthropometric measurement, and BP	Automated sphygmomanometer	Girls SBP (mmHg): BMI z score {β= 2.76 (95% CI 1.55, 3.95), R^2= 0.2, p<0.001 Model 2 SBP (mmHg): WC z score {β= 1.34 (95% CI 0.54, 2.12), R^2= 0.38, p<0.001 Model 3 SBP (mmHg): waist to height ratio	Age (at time of anthropometric measurement), pubertal stage, height, asthma, maternal education, household income and ethnicity.

		at ages 10 and 13 years were included. The association between adiposity measures at age 10 years and BP at age 13 years was explored.		{β= 26.05 (95% CI 1.69, 40.41), R^2= 0.11, p= 0.04 <u>Boys</u> SBP (mmHg): BMI z score {β= 2.69 (95% CI 1.52, 3.98), R^2= 0.3, p<0.001 Model 2 SBP (mmHg): WC z score {β= 2.19 (95% CI 1.52, 2.95), R^2= 0.34, p<0.001 Model 3 SBP (mmHg): waist to hip ratio {β= 32.81 (95% CI 13.17, 52.40), R^2= 0.27, p= 0.002 Model 4 SBP (mmHg): waist to height ratio {β= 43.12 (95% CI 25.41, 58.82), R^2= 0.31, p< 0.001	
Willig et al (America)	Cross sectional	281multi ethnic (92 African-American, 116 European-American, and 73 Hispanic-American) children aged 7-12 years were recruited from communities in Birmingham, Alabama. Participants were assessed for lifestyle,	Oscillometric device	<u>African-American</u> Model 1 SBP (mmHg): Fat mass (β=0.01, p=0.013) Model 2 SBP (mmHg): BMI (β=1.10, p<0.01) Model 3 SBP (mmHg): Waist (β=0.56, p<0.01) Model 4 SBP (mmHg): Waist height index	age, height, gender, socioeconomic status

		anthropometry, social and metabolic CVD risk factors. Ethnic differences in the association between anthropometry and BP was investigated		(β=8.00, p<0.01) <u>European-American</u> Model 1 SBP (mmHg): Fat mass (β=0.01, p<0.01) Model 2 SBP (mmHg): BMI (β=1.11, p<0.01) Model 3 SBP (mmHg): Waist (β=0.37, p<0.01) Model 4 SBP (mmHg): Waist height index (β=4.67, p=0.02) Hispanic-American associations were not significant	
Xu et al (China)	Cross sectional	This study is based on data from a large scale population survey of 29 997 (14 193 Chinese boys and 15 804 girls) aged 8-18 years recruited through a three stage cluster sampling used to identify eligible participants in each province. Study participants provided data on anthropometric characteristics, socio-demographic variables, lifestyle factors and BP.	Auscultatory method Hypertension was defined as average SBP and/or DBP levels ≥ 95th percentile for gender, age and height. High normal BP was defined as average SBP or DBP levels ≥ 90th percentile and < 95th percentile.	<u>Boys (hypertension)</u> Age (17 vs 8): (OR= 13.063, 95% CI 6.989, 24.415), Ethnicity (Yi vs Han): (OR= 1.960, 95% CI 1.665, 2.307), (Mongolia vs Han): OR= 1.283, 95% CI 1.070, 1.539), BMI (obesity vs normal weight): (OR= 3.377, 95% CI 2.771, 4.115), overweight vs normal weight): (OR= 2.009, 95% CI 1.762, 2.291) WC (≥ 90^{th} vs <90^{th}): (OR= 1.242, 95% CI 1.063, 1.452), Family history of CVD (yes vs no) (OR= 1.336, 95% CI 1.008, 1.772), Residence (Suburban or rural vs urban): (OR= 1.154, 95% CI 1.065, 1.250)	

		Risk factors associated with high blood pressure were investigated.		Girls (hypertension) Age (17 vs 8) : (OR= 8.700, 95% CI 4.685, 16.158), Ethnicity (Yi vs Han): (OR= 1.618, 95% CI 1.387, 1.887), BMI (obesity vs normal weight): (OR= 2.865, 95% CI 2.334, 3.517), overweight vs normal weight): (OR= 1.738, 95% CI 1.530, 1.975) WC (≥ 90th vs <90th): (OR= 1.212, 95% CI 1.061, 1.384), Residence (Suburban or rural vs urban): (OR= 1.210, 95% CI 1.119, 1.309)	

Prospective cohort study: studies that longitudinally examines the effect of risk factor or correlate with BP

Cross sectional study: studies that examine the effect of risk factor/correlates with BP at a specific time point

Case-control study: studies that compared individuals with elevated BP with those without to retrospectively examine risk factor exposure

BMI=Body mass index, WC=waist circumference, WHtR= waist to height ratio, FM= fat mass, FFM= fat free mass, IAAT= intra-abdominal adipose tissue, SAAT= subcutaneous abdominal adipose tissue, TER= trunk extremity skinfold ratio BPM= beats per minute, BP=blood pressure, SBP=systolic blood pressure, DBP= diastolic blood pressure, HTN=hypertension, SE= standard error, OR= odds ratio, CI= confidence intervals, SD=standard deviation, mmHg=millimetre of mercury.

Table A.2: Social correlates of BP

Study	Study design	Study Characteristics	Measurement of BP	Determinants/risk factors	Covariates
Barba et al (Italy)	Cross sectional	3551 children (1778 boys, 1773 girls) aged 6-11 years recruited as part of the Alimentazione nella Regione Campania (ARCA) study were assessed for anthropometric variables, and blood pressure. Maternal perception of body shape was also investigated. Associations between maternal perception of weight and blood pressure were examined.	Mercury sphygmomanometer	<u>Boys</u> SBP (mmHg): Maternal body shape perception below median (n=283) Mean= 95.1 (95% CI 93.4, 96.8), Median maternal body shape perception (n=1288) Mean=97.1 (95% CI 96.3, 97.9), Maternal body shape perception above the median (n=207) Mean=98.4 (95% CI 96.3, 100.4). p=0.01 DBP (mmHg): Maternal body shape perception below median (n=283) Mean= 60.3 (95% CI 59.1, 61.4), Median maternal body shape perception (n=1288) Mean= 61.0 (95%CI 60.4, 61.5), Maternal body shape perception above the median (n=207) Mean=63.1 (95% CI 61.7, 64.5). p=0.004 <u>Girls</u> SBP (mmHg): Maternal body shape perception below median (n=185) Mean= 93.7 (95% CI 91.2, 95.8), Median maternal body shape perception (n=1292) Mean=95.2 (95% CI 94.4, 95.9), Maternal body shape perception above the median (n=296) Mean=98.0 (95% CI 96.3, 99.7). p=0.001 DBP (mmHg): Maternal body shape	Age, birth weight, physical activity, parental overweight, parental education level, BMI

				perception below median (n=185) Mean= 58.3 (95% CI 56.7, 59.8), Median maternal body shape perception (n=1292) Mean= 59.9 (95% CI 59.4, 60.5), Maternal body shape perception above the median (n=296) Mean=60.9 (95% CI 59.6, 62.1). p=0.01	
Chen et al (America)	Cross sectional	Chinese-American 67 (38 boys, 29 girls) children aged 8-10 years old were recruited from Chinese language schools in the San-Francisco bay area. Children and their parents participate in an intervention aimed at improving health behaviour and psychosocial function. Participants were assessed for a range of social factors, anthropometry, lifestyle factors and BP at baseline, 3 months and 6 months. The study explores risk factors for elevated BP in Chinese-American children.	Mercury sphygmomanometer	SBP (mmHg): Unhealthy food choice {β = -0.40 (95% CI 0.07, 3.79), p = 0.04}, R^2 = 0.16, DBP (mmHg): Age {β = 0.68 (95% CI 3.95, 12.17), p = 0.001}, physical activity β = -0.49 (95% CI -0.006, -0.001), p = 0.008}, R^2 = 0.16	Age, gender, parental acculturation, dietary and physical activity self-efficacy, %fat intake, %sugar intake, average calorie intake

Clark et al (America)	Cross sectional	175 normotensive black participant recruited as part of a larger longitudinal study (n=225) were assessed for a range of demographic factors, a psychosocial variables including mood states, and violence exposure. Additionally, participants underwent an assessment that included a laboratory task aimed at eliciting physiological responses. BP was measured before and during the laboratory tasks. The relationship between the psychosocial variables and task induced changes in BP was explored.	Oscillometric device	Change in SBP (mmHg): violence exposure (β= -0.05, SE= 0.02, p<0.01), violence exposure X optimism (β= -0.07, SE= 0.03, p<0.01) Change in DBP (mmHg): violence exposure (β= -0.04, SE= 0.01, p<0.01)	Age, parental history of hypertension, BMI, gender, prescription drug use, performance ability, baseline SBP/DBP
Goosby et al (America)	Cross sectional	Data for this study come from the Omaha Urban Research on Health Study (OURHealth Study). Briefly, Low-	Digital sphygmomanometer	SBP (mmHg): Daily discrimination (β= 0.34, SE= 0.15, p≤ 0.05) DBP (mmHg): Daily discrimination (β= 0.47, SE= 0.15, p≤ 0.01)	Age adjusted BMI, WC, mother's education, age

		income African American and Caucasian mothers with a child between the ages of 10 and 15(n=43) were recruited through health fairs. The purpose of the study was to examine relationships between stressors, such as economic hardship, discrimination, and BP.			
Kaczmarek et al (Poland)	Cross sectional	This study recruited a total of 4941 participants (2451 male, and 2490 female) as part of the ADOPOLNOR study, a cross sectional study carried out in children ages 10-18 years of age. Study participants completed survey assessing a range of socio-economic variables and BP. The association between parental socioeconomic status	Mercury sphygmomanometer Pre-hypertension defined as systolic/diastolic BP greater than or equal to the 90th percentile but less than the 95th percentile. Hypertension defined as systolic/diastolic BP ≥ 95th percentile.	Prehypertension (SBP)= Female vs Male (OR= 1.24, 95% CI 1.01-1.54, p=0.039), Age 18 years vs age 10 years (OR= 1.23, 95% CI 1.06-2.01, p=0.046), Family history of hypertension, yes vs no (OR= 1.81, 95% CI 1.31-2.51, p=0.0003), Urban areas ≥ 100,000 vs rural areas (OR= 0.56, 95% CI 0.37-0.82, p=0.004), maternal education >12 years vs <12 years (OR= 0.60, 95% CI 0.48-0.91, p=0.002), Unemployed fathers vs employed fathers (OR= 1.53, 95% CI 1.04- 2.25, p=0.029), Not enough income vs more than enough income (OR= 1.40, 95% CI 1.17-1.94, p=0.019), obese category vs normal weight (OR= 8.42, 95% CI 5.33-12.28, p=<0.0001	Stepwise multinomial linear regression

		and offspring BP was explored.		Hypertension (SBP)= Female vs Male (OR= 0.77, 95% CI 0.59-0.91, p=0.045), Age 18 years vs age 10 years (OR= 1.39, 95% CI 1.09-2.13, p=0.038), Family history of hypertension, yes vs no (OR= 1.72, 95% CI 1.34-2.20, p<0.0001), Urban areas ≥ 100,000 vs rural areas (OR= 0.40, 95% CI 0.29-0.55, p<0.0001), maternal education >12 years vs <12 years (OR= 0.54, 95% CI 0.39-0.75, p=0.0002), obese category vs normal weight (OR= 9.75, 95% CI 6.91-13.75, p=<0.0001	
Kwok et al (China)	Prospective cohort	Participant in this study were recruited as part of the "children of 1997" study, a birth cohort of eligible children in Hong Kong. Families were recruited from maternal wards, and assessed for baseline socio-demographic characteristics. Routine information was collected on children weight and height from birth to age 5 and bi-annual assessment of BP afterwards. A total of 5604 participants make up the current study. The	Oscillometric device	SBP Z scores: Parental education x BMI at age 13 years (indirect effect): β= 0.02 (95% CI 0.0004, 0.04), proportion mediated (24%), Parental education x maternal BMI (Total effect): β= 0.01 (95% CI 0.004, 0.03), proportion mediated (18%)	Sex, birth order, mode of delivery, second-hand smoke, infant residency, parents age, parents birthplace, highest parental occupation, household income and housing.

		association between parental education at recruitment and BP at age 13 years, and the role of possible mediators was explored.			
McGrath et al (America)	Cross sectional	212 white and black participants ages 14 to 16 were recruited from two schools in Pittsburgh as part of a study to assess the relationship between social variables such as socio economic status, race and blood pressure.	Ambulatory blood pressure	SBP: Neighbourhood socioeconomic status (% at or below poverty) (β= 0.26, SE= 0.10, t=2.54, <0.01); Income (individuals at or below poverty) (β= 0.29, SE= 0.09, t= 3.19, p<0.01) DBP: Race (white adolescents compared black race) (β= -4.77, SE= 1.64, t= -2.91, p<0.01) Interaction effects SBP: White race (compared to blacks) x negative mood (β= -1.15, SE= 0.51, t=-2.26, <0.05); Individual household income x negative mood state (β= -0.02, SE= 0.01, t=-3.30, <0.001) DBP: White race (compared to blacks) x negative mood (β= -0.82, SE= 0.33, t= -2.47, <0.01); individual household income x negative mood state (β= -0.01, SE= 0.00, t=-2.54, <0.01); neighbourhood income (% at or below poverty) x negative mood state (β= 0.04, SE= 0.01, t=2.69, <0.01); neighbourhood race (% of black individuals) x negative mood state β= 0.01, SE= 0.00, t= -2.93, <0.01); neighbourhood	Location, BMI, posture, physical activity, race, gender, school, food consumption

				education (% with high school education or less) x negative mood state (β= 0.02, SE= 0.01, t=2.01, <0.05); individual race (white race) x location (β= -1.95, SE= 0.88, t= -2.20, <0.05; neighbourhood poverty rate x location (β= 0.15, SE= 0.05, t=3.11, <0.001; neighbourhood % of black individuals x location (β= 0.04, SE= 0.02, t=2.84, <0.01	

Prospective cohort study: studies that longitudinally examines the effect of risk factor or correlate with BP

Cross sectional study: studies that examine the effect of risk factor/correlates with BP at a specific time point

BMI=Body mass index, BP=blood pressure, SBP=systolic blood pressure, DBP= diastolic blood pressure, HTN=hypertension, SE=standard error, OR=odds ratio, CI= confidence intervals, mmHg=millimetre of mercury.

Table A.3: Lifestyle correlates of BP

Study	Study design	Study Characteristics	Measurement of BP	Determinants/risk factors	Covariates
Aeberli et al (Switzerland)	Cross sectional study	79 Swiss children aged 7-16 years old were recruited from primary schools and pediatric centres across a representative range of body sizes and assessed for diet and metabolic factors, including BP. The association between dietary content, and adiposity with BP was explored.	Auscultation using standard sphygmomanometer	SBP (mmHg): Total fat (β= 0.245, p= 0.014); saturated fatty acid (β= 0.242, p= 0.017); monounsaturated fatty acid (β= 0.227, p= 0.023) SBP (mmHg): BMI Z scores (β= 0.405, p<0.001); body fat % β= 0.359, p= 0.001	BMI, and age Age
Christofaro et al (Brazil)	Cross sectional	1231 adolescents ages 14-17 were recruited from six of the largest schools in the city of Londrina, Brazil. The six schools were selected because of their level of representation of the entire city. Data was collected on physical activity measures, anthropometry and blood pressure. The relationship between sedentary behaviour and blood pressure	Oscillometric device HBP: systolic and diastolic blood pressure at the 95th percentile.	HBP: Sedentary behaviour OR= 1.68 (95% CI 1.03- 2.75) p= 0.037 Cluster analysis HBP: Abdominal obesity + high Sedentary activity OR= 13.51 (95% CI 7.21- 23.97) HBP: Abdominal obesity + low Sedentary activity OR= 6.80 (95% CI 2.81- 16.45)	Age, gender, socioeconomic level, tobacco, alcohol, abdominal obesity, physical activity.

		was explored.			
Farajian et al (Greece)	Cross sectional	Participants in this study were recruited as part of the GRECO study, a cross sectional study of children aged 10-12 years old recruited from public schools in Greece. For this study, 2024 children who completed detailed dietary assessment, anthropometric measurements and BP assessment t were included. The relationship between diet, and anthropometry with BP was investigated.	Oscillometric device	High BP: Component 5 (high consumption of cheese and red processed meat)(OR= 1.15 95% CI1.03–1.30), Overweight vs normal weight (OR= 2.10 95% CI 1.61–2.73), Obese vs normal weight (OR= 3.84 95% CI 2.44–6.06)	Age, sex, breakfast frequency and BMI
Gaya et al (Portugal)	Cross sectional	2184 participants aged 8 to 17 years old were recruited into a longitudinal study exploring association between cardiovascular risk factors and physical activity from five primary and high schools. For this study, cross sectional data of 163 participants (66 boys, 97 girls) who	Oscillometric sphygmomanometer	SBP (mmHg): BMI{β= 1.39 p= 0.00 (95% CI 0.56, 2.23)}, Sedentary PA {β=0.04 p= 0.01 (95% CI 0.00; 0.08)} R^2= 0.204 DBP (mmHg): BMI{β= 0.19 p= 0.00 (95% CI 0.19, 1.24)} R^2= 0.14	Age, sex, height

		completed seven consecutive day accelerometer recording. Additionally, data on anthropometry, and BP were obtained. Association between anthropometry and physical activity with BP were explored.			
Hacke and Weisser (Germany)	Cross sectional study	532 children (271 boys and 261 girls) between ages 12-17 years) were recruited from six schools in northern Germany, and assessed for a range of anthropometric characteristics, parental characteristics and both exercise and resting blood pressure. The current analyses explores the relationship between parental factors with exercise and resting childhood blood pressure	Manual Sphygmomanometer	Resting SBP (mmHg): Parental hypertension {Mean difference +1.0 (95% CI 3.6, 4.7) p= 0.001; Familial hypertension {Mean difference +4.4 (95% CI 4.0, 4.6) p<0.001 Exercise SBP (mmHg): Parental smoking{Mean difference +4.0 (95%CI 3.1, 4.) p= 0.03; Parental hypertension {Mean difference +3.9 (95%CI 3.1, 4.8) p= 0.029; Familial hypertension {Mean difference +4.7 (95%CI 4.2, 5.3) p= 0.007; Inactive parents {Mean difference +4.9 (95%CI 3.5, 6.4) p= 0.013; low education level {Mean difference +5.2 (95%CI 4.3, 6.2) p= 0.006	Age, sex, height, BMI percentile, and physical fitness of adolescents
Lazarou et al (Cyprus)	Cross sectional	This study includes 622 participants age 10-13 years recruited as part of the Cyprus kids study from 24 schools	Mercury sphygmomanometer	Normal BP vs elevated BP: Watching TV while eating (OR= 2.24 95% CI 1.01–5.01), BMI (OR= 1.20, 95% CI 1.11–1.31)	Age, gender, SES, children's BMI (continuous), KIDMED dietary score (categorical),

		in Cyprus through multi-stage sampling. Participants were assessed for a range of lifestyle, social, anthropometric variables and BP. Associations between lifestyle and anthropometric characteristics were explored.			physical activity levels (that is, the physical activity index), time watching TV (categorical) and a variable that measures the interaction of TV watching and eating at the same time
Maximova et al (Canada)	Prospective cohort	Study participants were recruited as part of an ongoing prospective cohort study called the Nicotine Dependence in Teens Study. At baseline, a total of 1293 grade 7 students aged 12-13 years were recruited from 10 schools in Montreal, Canada, and followed up for a 5-year period. Assessments were carried out every 3 months during the 10-month school year for the 5-year period. A total of 869 participants completed the full assessment, and the analysis was	Oscillometric device	SBP (mmHg) at early adolescence (age 15 years) Girls: SBP at baseline {β=0.55 (95%CI 0.53, 0.58)}; MVPA (sessions/week) Initial level {β= -0.12 (95%CI -0.15, -0.08)} Rate of decline {β=0.30 (95%CI 0.07, 0.52)}; Age {β= -0.14 (95%CI -0.79, 0.52)}; Height (cm) Initial level {β=0.12 (95%CI 0.05, 0.19)} Change in height {β= -0.35 (95%CI -1.63, 0.92)} Interaction {β=0.00 (95%CI 0.00, 0.01)} Smoking {β=0.03 (95%CI 0.01, 0.04)} BMI Initial level {β=0.27 (95%CI 0.19, 0.35)} Change in BMI {β= 2.74 (95%CI 2.02, 3.45)} Interaction {β= -0.08 (95%CI -0.11, -0.05)} R^2 value = 0.33 SBP (mmHg) at Late adolescence (age 17	Individual growth modelling used

		stratified by early adolescence (age 15 years), and late adolescence (age 17 years)		years) Girls: SBP at baseline {β=0.59 (95%CI 0.57, 0.62)}; MVPA (sessions/week) Initial level {β= -0.06 (95%CI -0.12, -0.01)} Rate of decline {β=0.55 (95%CI 0.29, 0.81)}; Age {β= 0.31 (95%CI -0.44, 1.06)}; Height (cm) Initial level {β=0.20 (95%CI 0.14, 0.26)} Change in height {β= 14.20 (95%CI 8.70, 19.70)} Interaction {β= -0.09 (95%CI -0.12, -0.05)} Smoking {β=0.02 (95%CI 0.01, 0.03)} BMI Initial level {β=0.26 (95%CI 0.18, 0.34)} Change in BMI {β= 1.50 (95%CI 0.73, 2.27)} Interaction {β= 0.11 (95%CI 0.08, 0.14)} R^2 value = 0.46	
Moraes et al (Eight European countries (Germany, Hungary, Italy, Cyprus, Spain, Estonia, Sweden, Belgium)	Prospective cohort study	Participants for this analysis were recruited as part of the Identification and prevention of Dietary- and lifestyle-induced health Effects In Children and infants (IDEFICS) study. The IDEFICS study is an ongoing study in multicenter prospective cohort study that aims to identify lifestyle related factors of	Oscillometric device HBP defined as SBP or DBP above the 95th percentile for age and height	High blood pressure: Physical activity (Reference group = ≥ 60 min/day) <60min/day (RR= 1.53 (95% CI 1.12, 2.09)	Country, seasonality, sex, age, parental education and waist circumference

		obesity. 16,228 children (aged 2-9) were recruited at baseline and followed up for two years. A total of 5061 participants completed full follow up measures and were included as part of the study assessment.			
Normia et al (Finland)	Prospective cohort	109 singleton children born full term to mothers who were part of a randomised placebo-controlled trial with concurrent dietary counselling and probiotic intervention during gestation were followed from birth until the age of four years. The role of maternal dietary characteristics at pregnancy in influencing blood pressure of children at four years were assessed.	Oscillometric device	SBP at 4 years (mmHg): Childhood weight at4 years (β =1.9 (95% CI 1.2, 2.6) P<0.001); childhood fat intake at 4 years (p= 0.013); Maternal fat intake during pregnancy (p=0.003); Maternal carbohydrate intake (270-447 gram of carbohydrate intake compared to reference group of 157-238 grams) (β= 5.8 (95%CI 2.5, 9.0) p=0.001)	Step wise regression used
Setayeshgar et al (Canada)	Prospective cohort	Participant in this study were recruited as part of the ongoing healthy hearts study, a prospective study of cardiometabolic risk	Oscillometric device	SBP z score: Dietary fat 10g/day{β= 0.03 (95% CI 0.00004, 0.06), p<0.05} DBP z score: Dietary fat 10g/day{β= 0.03 (95% CI 0.003, 0.05), p<0.05}, sodium, g/day {β= 0.04 (95% CI 0.006, 0.07), p<0.05}	Baseline BMI z scores, physical activity, SBP/DBP, year of participation

		factors in youth. At baseline, 2189 students in grades 5 to 10 were recruited from 14 schools in rural and urban areas in Edmonton, Alberta. Participants were assessed for measures of dietary intake, cardio metabolic factors and lifestyle factors. A total of 448 students with at least one follow up visit and complete dietary and physical activity analyses were included in this study. The association between dietary factors at baseline and changes in cardio metabolic risk factors including blood pressure was investigated.			
Simonetti et al (Germany)	Cross sectional	4236 preschool children (mean age 5.7 ± 0.4 years) in a southwestern district of Germany were assessed for a compulsory physical and cognitive testing. As part of this study,	Aneroid sphgmomanometer	SBP(mmHg): parental smoking (β= 0.8442, SE= 0.3059, p=0.006)	Gender, BMI, height, gestational age, birth weight, parental hypertension, parental educational status, parental obesity, gestational hypertension, maternal smoking

		the preschool children were additionally tested for BP, anthropometric variables, and a detailed medical, and social history. The role of parental smoking on childhood BP was investigated.		<u>Stepwise linear regression</u> SBP (mmHg): Gender (β= -0.9064, SE= 0.2587 p=0.0005), BMI (β=0.9932, SE= 0.0741, p<0.0001), Height (β= 0.3136, SE= 0.0252, p<0.0001), Birth weight (β= -1.2348, SE= 0.2458 p<0.0001), Parental hypertension (β= 1.4761 SE= 0.3922, 0.0002), Parental smoking (β= 0.7960, SE= 0.2706, p=0.003), Gestational hypertension (β= 1.2105 SE= 0.5563, p= 0.03) Adjusted R^2= 0.1444 DBP (mmHg): Gender (β= -0.5184, SE= 0.2203 p=0.02), BMI (β=0.6663, SE= 0.0623, p<0.0001), Height (β= 0.1425, SE= 0.0214, p<0.0001), Birth weight (β= -0.7047, SE= 0.2065 p<0.0007), Parental hypertension (β= 1.2337, SE= 0.3251, p=0.0002) Adjusted R^2= 0.0648	
Tamai et al (Japan)	Cross sectional study	459 healthy children aged 3 to 6 years were recruited from two kindergartens in Aichi, Japan, and assessed for information on anthropometric, lifestyle, and three consecutive days	Automated sphygmomanometer	<u>Model 1</u> SBP (mmHg): Vitamin B12 Quartile 1 (≤2.43µg/day)= 102.0 (95% CI 99.5-104.5) Quartile 2 (2.44-3.29µg/day)= 99.2 (95% CI 96.8-101.6) Quartile 3 (3.30-4.59µg/day)= 99.0 (95% CI 96.5-101.4) Quartile 4 (≥4.60µg/day)= 95.9 (95% CI	Age, sex, BMI, sodium intake, potassium intake, school difference, smoking status of parents

		dietary record.		93.4-98.3) p=0.004 for trend DBP: Quartile 1 (≤2.43µg/day)= 63.9 (95% CI 61.6-66.1) Quartile 2 (2.44-3.29µg/day)= 61.5(95% CI 59.4-63.8) Quartile 3 (3.30-4.59µg/day)= 61.6 (95% CI 59.4-63.8) Quartile 4 (≥4.60µg/day)= 58.1(95% CI 55.9-60.3) p=0.01 for trend Model 2 SBP (mmHg): Folic acid Quartile 1 (≤156µg/day)= 100.5 (95% CI 97.7-103.2) Quartile 2 (157-185µg/day)= 100.8 (95% CI 98.3-103.2) Quartile 3 (186-228µg/day)= 98.4(95% CI 96.0-100.9) Quartile 4 (≥229µg/day)= 96.4 (95% CI 93.6-99.2) p=0.02 for trend Values are= estimated mean (95% CI)	

Prospective cohort study: studies that longitudinally examines the effect of risk factor or correlate with BP

Cross sectional study: studies that examine the effect of risk factor/correlates with BP at a specific time point

BMI=Body mass index, BP=blood pressure, SBP=systolic blood pressure, DBP= diastolic blood pressure, HTN=hypertension, SE= standard error, MVPA= moderate to vigorous physical activity, CI= confidence intervals, mmHg=millimetre of mercury

Appendix A.2

Interview Guide

Introductory question: In your opinion, what do you think people (both children and adults) can do to reduce their risk of heart disease?

South Asian's have been shown to be at increased risk for heart disease risk, and this risk has been shown to be present in children. What are some of the reasons you consider responsible for this?

Physical activity- Adults

Physical activity plays an important role in reducing cardiovascular disease risk. As a result, we will like to seek your opinion on the following:

- What do you consider as exercise or physical activity? Please provide examples if you can.
- What kinds of physical activity/exercise would you be most likely to take part in? Why?
- What kinds of exercise are you least likely to participate in? Why?
- What do you consider the biggest barrier to being physically active?
- Are there any religious/cultural factors that tend to influence your decision to, or not to participate in physical activity?
- For those who engage in regular physical activity, what factors do you consider as motivators to participating in regular physical activity.
- Do you encourage your children to be physically active?

Children

- What does it mean to be healthy? What are some of the things you need to do to stay healthy?
- Do you think physical activity is important to the health of children?
- When are you the most physically active? School, home or with friends?
- Do you enjoy exercising or being physically active?

- Is there anything/ anyone that stops you from being physically active (TV, computer games, friends)

Nutrition- Adults

Diet plays an important role to heart disease risk. As a result, we will like to seek your opinion on the following questions:

- Do you consider diet/nutrition as an important factor to attaining good cardiovascular health?
- What do you think healthy eating means?
- In your opinion, what should constitute a healthy diet? Does your diet meet these requirements?
- What is your general perception of the traditional South Asian diet?
- What are some of the qualities of the South Asian diet you think needs to be improved on to achieve good heart health?
- Do you read food labels before purchasing them from the grocery store?
- What are some of the barriers you and your family face to eating healthy?
- What are some of the things that motivate you to eating healthy?
- In your opinion, what are some of the things that can be done to increase awareness of healthy behaviours?
- Asides from healthy eating and exercise, what other thing do you think can help improve heart health or reduce your risk of heart disease?

Children

- What do you know about what makes a healthy diet?
- Do you think eating healthy now helps you when you get older?
- Are there any types of foods you are not allowed to eat?
- Where else do you eat apart from your home? And what kind of foods do you eat there?
- Are there any foods you think are not good for you? Give me examples.
- Would you say that your diet is healthy? What are some of the things that make you want to eat healthy?
- If your diet is not healthy, what stops you from eating healthy?

- Are you likely to eat healthier or exercise more if your favorite celebrity were doing same on social media? If yes, why?