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## Multifactorial correlates of blood pressure in South Asian children: a cross-sectional study

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Manuscripts

**Multifactorial correlates of blood pressure in South Asian children: a cross-sectional study.**

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**Running title: Correlates of blood pressure in South Asian children**

**Keywords:** South Asian, children, hypertension, risk factors

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## ABSTRACT

**Objective:** South Asian adults are at greater risk for cardiovascular disease risk factors. In South Asian children, studies have documented higher blood pressure (BP) values and hypertension rates than in Caucasian children. To effectively address the burden of hypertension in this population, an understanding of associated factors is necessary. We sought to explore various correlates of BP and hypertension in South Asian children.

**Design:** Cross-sectional study

**Setting:** Community-based recruitment in two Canadian cities (Hamilton and Surrey)

**Participants:** South Asian children (n=762) from two Canadian cities provided a range of physiological, behavioural and social variables. Blood pressure was assessed using an automated device. Body mass index, waist circumference, waist-to-height ratio and BP were transformed to z-scores using published standards.

**Outcome measures:** Regression analyses were used to explore associations among the range of physiological, behavioural and social factors with BP z-scores and hypertension and to identify the factors that provided the best explanatory capacity for systolic and diastolic BP z-scores.

**Results:** A range of physiological, social and behavioural factors were associated with BP z-score and hypertension in unadjusted analysis; however, upon adjustment for covariates, the association between most social and behavioural factors attenuated while the association between the physiological factors remained. In stepwise regression, age, sex, BMI z-score, heart rate and weight accounted for 30% of the variance of BP z-score, while age, BMI z-score, heart rate and daily intake of fast foods accounted for 23% of the diastolic BP z-score variance.

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3 **Conclusion:** Our findings suggest that physiological variables such as age, sex, height, adiposity,  
4 and heart rate provide stronger explanatory capacity to BP variance and hypertension risk than  
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6 other multifactorial variables in South Asian children.  
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For peer review only

## ARTICLE SUMMARY

### Strengths and limitations of this study

- The strengths of this study includes its large sample size of South Asian children and,
- Its examination of a wide range of physiological, behavioural and social risk factors in relation to BP z-scores and hypertension in South Asian children.
- Limitations of the study includes its cross-sectional design which limits the attribution of causality.

## INTRODUCTION

South Asians comprise approximately 25% of the world's global population<sup>1</sup> and represent a significant portion of the visible ethnic minority groups in countries such as Canada, the United Kingdom and the United States (US)<sup>2-4</sup>. Individuals of South Asian origin are known to be at increased risk of cardiovascular disease (CVD) relative to other ethnic groups in Western countries<sup>5,6</sup>. 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<sup>7</sup>.

One of the major physiological risk factors for CVDs is high blood pressure (BP) or hypertension<sup>8</sup>. Hypertension is also associated with an increased risk for stroke and kidney disease<sup>8</sup>. Moreover, multiple studies have shown that high BP in childhood typically continues into adulthood<sup>9</sup> — including in South Asian populations<sup>10</sup>. These findings suggest that it is essential 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 increased prevalence of hypertension or higher BP levels relative to other ethnic groups<sup>11,12</sup>. 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<sup>8</sup>, it is vital 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 that were identified in a recently published systematic review of children to be correlated with BP and hypertension in other children population groups<sup>13</sup>, this study therefore aims: 1) to explore the associations

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3 between physiological, lifestyle and socio-demographic factors and BP in South Asian children;  
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5 and 2) to identify the most important aggregate correlates of BP in South Asian children.  
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## 8 **METHODS**

### 9 **Study Design**

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15 Participants included in this study were recruited as part of the Research in International  
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17 Cardiovascular Health - Lifestyles, Environments and Genetic Attributes in Children and Youth  
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19 (RICH-LEGACY) study. This cross-sectional study is designed to investigate risk factors for  
20  
21 CVD across South Asian children in Canada. The study was approved by the Simon Fraser  
22  
23 University Research Ethics Board (REB), Providence Health Care REB, and the Hamilton  
24  
25 Integrated REB. Parents of participants provided written informed consent, while participants  
26  
27 assented to take part in the study.  
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### 31 **Recruitment**

32  
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35 Elementary school and high-school children (n= 762) were recruited using community-  
36  
37 based methods in two Canadian cities (Brampton, Ontario and Surrey, British Columbia) by  
38  
39 convenience sampling between 2012 and 2016. Elementary schools with a high rate of South  
40  
41 Asian enrolment were first identified by contacting the school boards. Once schools were  
42  
43 identified, packages containing an invitation letter, a RICH-LEGACY study description and  
44  
45 consent forms were sent to parents/guardians of children enrolled in the identified schools.  
46  
47 Information stands were also placed at the participating elementary schools before and after  
48  
49 school hours to reach out to parents with more information about the study. Additionally, the  
50  
51 study was advertised through venues used by South Asian groups including newspapers, local  
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53 television stations, community centres, worship centres and festivals. Inclusion criteria included:  
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3 children (in elementary or high school) having at least three grandparents of South Asian origin;  
4 and participants being able to provide consent (parents) and assent (children). Research assistants  
5  
6 fluent in Hindi and Punjabi were responsible for participant recruitment and data collection. The  
7  
8 research assistants who were involved in the measurements all undertook training together  
9  
10 through simulator sessions and were retrained if variations in measurement protocol were  
11  
12 observed by the research coordinator. This process was repeated for a few days to ensure  
13  
14 accuracy and consistency amongst the research assistants in the assessment of the measurements  
15  
16 collected in this study. In addition, written materials (including consent forms) were provided in  
17  
18 English, Punjabi, Hindi and Urdu as needed.  
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### 24 **Participant Assessment**

25  
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27  
28 Participants for the RICH-LEGACY study were assessed regarding socio-demographic  
29  
30 variables including age, sex and parental education. In certain cases, parents or guardians helped  
31  
32 complete certain sections of the child's questionnaire. Children's perception of body image was  
33  
34 assessed using Stunkard's silhouettes, a rating scale from one to nine with increases related to  
35  
36 increased silhouette size<sup>14</sup>, that assesses perception of size and body dissatisfaction. This figure  
37  
38 rating scale has been shown to be a valid indicator of determining weight status in children<sup>15</sup>.  
39  
40 Feeding practices were assessed using the childhood feeding questionnaire<sup>16</sup>. Exposure to  
41  
42 bullying was assessed by asking participants if they had experienced bullying or violence at  
43  
44 school. This variable was assessed because of its role as a known stressor in children and its  
45  
46 possible impact on pathways known to be involved in BP regulation such as the hypothalamic-  
47  
48 pituitary-adrenal (HPA) axis<sup>17</sup>. Additionally, level of acculturation was assessed using the  
49  
50 Acculturation Rating Scale for Mexican Americans-II (ARSMA- II) adapted for use in South  
51  
52 Asians by Stigler *et al*<sup>18</sup>. This scale assesses an individual's identification with their heritage  
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3 based on different domains including language preferences, media preferences, and preferences  
4 regarding food and other consumer goods using 24 questions<sup>18</sup>. The adapted questionnaire is  
5  
6 grouped into two scales: the Western scale and the traditional scale. The traditional acculturation  
7  
8 score measures children's acceptance of traditional Indian cultural attributes while the  
9  
10 Westernized acculturation score measures the degree to which South Asian children identify with  
11  
12 Western culture.  
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17  
18 Participants completed a semi-quantitative food frequency questionnaire (FFQ) that  
19  
20 assessed intake of fruits and vegetables and fast foods consumption. The FFQ was adapted from  
21  
22 the INTERHEART FFQ, which was validated in an international cohort that included South  
23  
24 Asians<sup>19</sup>. Physical activity was assessed using a questionnaire that quantified sports and other  
25  
26 activities including leisure, household chores and sedentary factors (screen time and homework)  
27  
28 during school and outside of school over the past month— with all activities then expressed as  
29  
30 metabolic-equivalent-of-task (MET) minutes. Self-reported exposure to second-hand smoke was  
31  
32 assessed to characterize children's passive exposure to smoking and defined as a minimum of  
33  
34 five consecutive minutes during which inhalation of other people's smoke occurs. Hand-grip  
35  
36 strength, a measure of muscular strength, was measured on the non-dominant hand by study  
37  
38 personnel with a Jamar dynamometer utilizing standardized protocol<sup>20</sup>.  
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#### 44 **Anthropometric Characteristics**

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46 Height was measured to the nearest 0.1 cm using a right angle triangle and a calibrated  
47  
48 wall mounted scale. Weight was measured to the nearest 0.1 kg with the subject in light clothing  
49  
50 using an electronic scale. Body mass index (BMI) was first calculated from weight in kilograms  
51  
52 divided by height in meters squared before being converted to z-scores using WHO growth  
53  
54 references for young people aged 5-19 years<sup>21</sup>.  
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3           Waist circumference (WC) was recorded in centimetres as the average of two measures  
4  
5 taken halfway between the lower rib margin and the iliac crest against the skin following a  
6  
7 normal expiration. Waist circumference was assessed using non-stretching measuring tape by  
8  
9 trained team members. Waist-to-height ratio (WtHR) was then calculated by dividing waist  
10  
11 circumference by height. Both WC and WtHR were transformed to z scores using recently-  
12  
13 published values for age and sex based on the third US National Health and Nutrition  
14  
15 Examination Survey (NHANES III)<sup>22</sup>. Transforming the anthropometric measures to z-scores  
16  
17 allowed for the standardized comparisons across populations of children of similar ages and sex.  
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### 20 21 **Blood Pressure and Heart Rate**

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24           Blood pressure and heart rate were measured in the left arm using the Omron HEM-  
25  
26 711DLX automated blood pressure monitor with appropriate sized cuffs following 10 minutes of  
27  
28 seated rest. Three BP and heart rate measures were taken over a 10-minute period and the  
29  
30 average of the three was recorded. Subsequently, BP was transformed to standard deviation  
31  
32 scores and percentiles adjusted for age, sex and height according to the fourth National High  
33  
34 Blood Pressure Education Program (NHBPEP) working group in children and adolescents<sup>23</sup>.  
35  
36 Systolic and diastolic hypertension were defined using the NHBPEP recommendations as  
37  
38 average systolic blood pressure or diastolic blood pressure equal to or greater than the 95<sup>th</sup>  
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40 percentile for sex, age and height.  
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### 45 46 **Parental Variables**

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49           Parents of the children recruited for this study provided information on parental education  
50  
51 (father's and mother's education). In a smaller subset of the South Asian children (n=271),  
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53 parental history of hypertension (yes or no) was assessed in order to explore the potential impact  
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3 of heritable factors on children's BP z-scores and hypertension. Socioeconomic status was  
4 determined according to father's education, owing to widely reported cultural influences on  
5 gender structures in the South Asian population<sup>24</sup>. Fathers' education levels were categorized as:  
6 those with no formal education; those with primary/secondary school education; those with a  
7 trade school degree/diploma; and those with a college or university degree. Parent's smoking  
8 status was self-reported and categorized as non-smoker, former smoker, or current smoker.  
9

### 18 **Statistical Analysis**

20  
21 All continuous variables were examined using P-P plots and found to be normally  
22 distributed. For descriptive analysis, continuous variables were presented as means and standard  
23 deviations while categorical variables were reported as counts and percentages. Independent t-  
24 test analysis was used to assess sex differences in continuous variables, while chi-square tests  
25 were used to assess sex differences in categorical variables.  
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33 To explore the associations among the range of physiological, behavioural and  
34 sociodemographic variables with systolic and diastolic BP, unadjusted linear regression was  
35 used. These models were then adjusted for child age, sex and father's education. These  
36 confounders were selected based on their well –documented independent associations with the  
37 outcome variable in research studies. Although, the conversion to z-scores provides age and sex  
38 adjusted data, we chose to still include age and sex as confounders to adjust for potential residual  
39 effects because the growth chart used by the NHANES might not adequately reflect the growth  
40 profile of South Asian children. Similarly, unadjusted and adjusted (age, sex and father's  
41 education) logistic regression analysis was used to explore clinically-relevant associations among  
42 the multifactorial correlates with systolic and diastolic hypertension. To evaluate the independent  
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3 effect of sex and age in the adjusted models, they were each removed from the list of covariates  
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5 when exploring their effect on BP z-scores and hypertension (i.e., sex was adjusted for age and  
6  
7 father's education), while age was adjusted for sex and father's education.  
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10  
11       Following linear regression, stepwise multiple linear regression analyses were used to  
12  
13 identify the combination of risk factors that best explained the variance in BP in South Asian  
14  
15 children. The stepwise regression method enables the identification of the aggregate combination  
16  
17 of correlates that has the highest contributory effect to the outcome variable. Specifically, for this  
18  
19 analysis, we utilized the backward method to select the list of multifactorial correlates that  
20  
21 provide significant contribution to the outcome (systolic and diastolic BP z-scores) using an  
22  
23 entry criterion of  $p < 0.05$  and a removal criterion of  $p > 0.10$ . The specific list of correlates (age,  
24  
25 sex, height, weight, heart rate, BMI z-score, WC z-score, WHtR z-score, parental history of  
26  
27 hypertension, parental education, exposure to bullying and violence, traditional and western  
28  
29 acculturation scores, physical activity in school and outside school, dietary variables and second-  
30  
31 hand smoking) considered for introduction in the backward stepwise regression model were  
32  
33 chosen *a priori* based on literature evidence<sup>13</sup> and whether they had a p value  $< 0.05$  in univariate  
34  
35 analysis. Using the aforementioned criteria, the following variables were considered in step-wise  
36  
37 regression analysis: age, sex, height, weight, BMI z-score, WC z-score, WHtR z-score, heart  
38  
39 rate, western acculturation score, child's perception of body image, and grip strength. In addition  
40  
41 to these variables, father's education, daily intake of fast foods and total daily intake were  
42  
43 considered in diastolic BP z-score models. The full lists of variables initially identified from  
44  
45 literature search were considered in hypertension models. Statistical analysis was done using  
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47 SPSS version 24.0. P values  $< 0.05$  were considered statistically significant. This study was  
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3 written in line with the Strengthening the Reporting of Observational studies in Epidemiology  
4 (STROBE) guidelines<sup>25</sup>  
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6

## 7 8 **Patient and Public Involvement** 9

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11 The research questions and outcome measures in this study were chosen by this team of  
12 researchers and clinicians with extensive experience working with the South Asian population to  
13 better understand the potential health risks faced by South Asian children. No patients were  
14 involved in setting the research question in development of the research question or study design.  
15  
16 There are currently no plans to disseminate the results of this research study to study participants  
17 or to the relevant patient population.  
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## 26 **RESULTS** 27

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29 This study included 360 boys and 402 girls ranging from 5.8 to 17.0 years (mean age 9.5  
30  $\pm$  3.0 years), with no statistically significant difference observed for age by sex. Mean non-  
31 transformed systolic BP was 109  $\pm$  11 mmHg while mean diastolic BP was 65  $\pm$  8 mmHg. The  
32 prevalence of systolic hypertension in this population was 12%. South Asian boys were more  
33 physically active outside school than girls ( $p=0.04$ ); were more likely to have a maternal history  
34 of hypertension ( $p=0.047$ ); higher WC z-score ( $p<0.001$ ); higher WHtR z-score ( $p=0.02$ ); lower  
35 heart rate ( $p=0.047$ ); higher systolic BP z-scores ( $p=0.001$ ); higher non-transformed systolic BP  
36 ( $p<0.001$ ); higher prevalence of systolic hypertension ( $p=0.01$ ); had lower traditional  
37 acculturation score ( $p=0.02$ ); and significantly higher exposure to bullying and violence at school  
38 ( $p=0.025$ ) (Table 1).  
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## 53 **Correlates of Systolic BP and Systolic Hypertension** 54 55 56 57

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3 In univariate linear regression analysis with systolic BP z-scores, weight (kg) ( $\beta= 0.005$ ,  
4 95% CI= 0.001, 0.01,  $p=0.022$ ), BMI z-score ( $\beta= 0.289$ , 95% CI= 0.246, 0.333,  $p<0.001$ ), WC z-  
5  
6 score ( $\beta= 0.266$ , 95% CI= 0.213, 0.319,  $p<0.001$ ), WHtR z-score ( $\beta= 0.271$ , 95% CI= 0.219,  
7  
8 0.324,  $p<0.001$ ), heart rate (beats per minute) ( $\beta= 0.019$ , 95% CI= 0.015, 0.023,  $p<0.001$ ), and  
9  
10 the child's perception of their body image (using Stunkard's silhouettes) ( $\beta= 0.136$ , 95% CI=  
11  
12 0.083, 0.189,  $p<0.001$ ) were found to be positively associated with systolic BP z-score. In  
13  
14 contrast, we found that compared to male sex, female sex had lower systolic BP z-score ( $\beta= -$   
15  
16 0.246, 95% CI= -0.385, -0.108,  $p<0.001$ ). Similarly, age (years) ( $\beta= -0.060$ , 95% CI= -0.084, -  
17  
18 0.037,  $p<0.001$ ), children's western acculturation score ( $\beta= -0.021$ , 95% CI= -0.036, -0.006,  
19  
20  $p=0.007$ ) and height (cm) ( $\beta= -0.006$ , 95% CI= -0.010, -0.002,  $p=0.007$ ) were negatively  
21  
22 associated with systolic BP z-score. After adjustment for covariates the association between age,  
23  
24 sex, weight, BMI z-score, WC z-score, WHtR z-score, heart rate and children's perception of  
25  
26 body image with systolic BP z-scores remained— while the association with height became  
27  
28 positive, and positive associations between children's grip strength and daily physical activity in  
29  
30 school with systolic BP z-score was observed upon adjustment (Table 2).  
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39 In stepwise regression analysis, the combination of age, sex, BMI z-score, heart rate and  
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41 weight were observed to be the most important correlates of systolic BP z-score, accounting for  
42  
43 30% of the systolic BP z-score variance of South Asian children (Table 3).  
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46  
47 In unadjusted logistic regression analysis, female sex was associated with lower odds of  
48  
49 developing systolic hypertension (odds ratio (OR) = 0.56, 95% CI= 0.36, 0.87,  $p=0.011$ ).  
50  
51 Associations were also observed with weight (kg) and systolic hypertension (OR= 1.02, 95%  
52  
53 CI= 1.01, 1.04,  $p<0.001$ ), BMI z-score and systolic hypertension (OR= 2.22, 95% CI= 1.84,  
54  
55 2.68,  $p<0.001$ ), WC z-score and systolic hypertension (OR= 2.65, 95% CI= 2.06, 3.43,  $p<0.001$ )  
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3 and WHtR z-score and systolic hypertension (OR= 2.47, 95% CI= 1.95, 3.13,  $p<0.001$ ).  
4  
5 Similarly, associations were observed between heart rate (beats per minute) and systolic  
6  
7 hypertension (OR=1.04, 95% CI= 1.02, 1.06,  $p<0.001$ ), child's perception of body image and  
8  
9 systolic hypertension (OR= 1.50, 95% CI= 1.25, 1.79,  $p<0.001$ ) and western acculturation score  
10  
11 (OR= 0.95, 95% CI=0.90, 1.00,  $p=0.03$ ). Upon adjustment for covariates, the associations  
12  
13 between sex, height, weight, BMI z-score, WC z-score, WHtR z-score, heart rate and child's  
14  
15 perception of body image remained — while the association between grip strength and systolic  
16  
17 hypertension became significant upon adjustment (Figure 1).  
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### 22 **Correlates of Diastolic BP and Diastolic Hypertension**

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24  
25 In univariate linear regression analysis of multifactorial variables with diastolic BP z-  
26  
27 score, negative associations with diastolic BP z-score were observed between age (years) ( $\beta= -$   
28  
29  $0.061$ ,  $p<0.001$ ), height (cm) ( $\beta= -0.009$ ,  $p<0.001$ ), western acculturation score ( $\beta= -0.018$ ,  
30  
31  $p=0.007$ ), fathers' level of education ( $\beta= -0.054$ ,  $p=0.047$ ), total daily food intake ( $\beta= -0.016$ ,  
32  
33  $p=0.005$ ), fast foods ( $\beta= -0.065$ ,  $p=0.048$ ) and grip strength (kg) ( $\beta= -0.019$ ,  $p<0.001$ ).  
34  
35  
36 Conversely, significant positive associations with diastolic BP z-score were observed between  
37  
38 heart rate ( $\beta= 0.018$ ,  $p<0.001$ ), BMI z-score ( $\beta= 0.156$ ,  $p<0.001$ ), WC z-score ( $\beta= 0.120$ ,  
39  
40  $p<0.001$ ), WHtR z-score ( $\beta= 0.128$ ,  $p<0.001$ ), and children's perception of their body image  
41  
42 (using Stunkard's silhouettes) ( $\beta= 0.053$ ,  $p=0.007$ ). After adjustment for covariates the  
43  
44 association remained between age, weight, BMI z-score, WC z-score, WHtR z-score, heart rate  
45  
46 and children's perception of body image with diastolic BP z-score, while the association between  
47  
48 physical activity in school with diastolic BP z-score became significant (Table 2).  
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3 In stepwise regression analysis, the combination of age, BMI z-score, heart rate and daily  
4 intake of fast foods were observed to be the most important aggregate correlates of diastolic BP  
5 z-score, accounting for 23% of the diastolic BP z-score variance of South Asian children (Table  
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13 In unadjusted logistic regression analysis, associations were observed between age  
14 (years) (OR= 0.71, 95% CI= 0.55, 0.92, p=0.01), height (OR= 0.97, 95% CI= 0.94, 1.00,  
15 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%  
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17 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  
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19 (beats per minute) (OR=1.06, 95% CI= 1.03, 1.10, p<0.001) and grip strength (kg) (OR= 0.92,  
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21 95% CI= 0.86, 0.99, p=0.024) with diastolic BP z-score. The association with age, BMI z-score,  
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23 WC z-score, WHtR z-score and heart rate remained significant after adjustment for covariates,  
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25 while the association with weight became significant (Figure 2).  
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## 32 **DISCUSSION**

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35 This study provides information on the multifactorial correlates of systolic and diastolic  
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37 BP z-scores in a population of South Asian children. While results from unadjusted models  
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39 highlight the presence of a multifactorial relationship for BP and hypertension, the disappearance  
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41 of most of the social and lifestyle risk factors upon adjustment highlights the contribution of  
42  
43 physiological variables such as age, sex, adiposity, height, heart rate, and grip strength to the risk  
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45 of elevated BP and hypertension in South Asian children.  
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50 It is well documented that the burden of hypertension has precipitously increased in the  
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52 pediatric population<sup>26</sup>. In addition, some studies have documented higher prevalence of  
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54 hypertension in certain ethnic groups such as South Asians<sup>11</sup>. Although our sample was based on  
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3 convenience and non-representative given that sampling was restricted to two Canadian cities,  
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5 the prevalence of hypertension in our study at 12% is consistent with age, sex and height  
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7 adjusted estimates from Jafar *et al*<sup>11</sup> using a nationally-representative survey of Pakistani  
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9 children age 5 to 14 years, but higher than 5.2% prevalence from one cross-sectional study of  
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11 Indian children ages 5 to 12 years<sup>27</sup>. Our estimates also appear higher than estimates from  
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13 Canadian children ages 6 to 19 years where 4% of children were said to have hypertension and  
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15 prehypertension<sup>28</sup>. When stratified by sex, we found significantly higher rates were observed for  
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17 boys at 15% compared to girls at 9%. This is consistent with results from studies in other  
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19 children which have reported higher hypertension prevalence in boys<sup>29,30</sup>, and results from  
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21 regression analysis which found female sex to be associated with lower odds of hypertension.  
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23 This risk differential has been attributed to the presence of an anti-inflammatory immune profile  
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25 in females and pro-inflammatory profile in males<sup>31</sup> — underscoring the potential for intervention  
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27 efforts aimed at addressing sex-based disparities.  
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34 Consistent with research conducted in South Asian children<sup>11,32</sup> and research conducted  
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36 in other childhood populations of different ethnicities<sup>29,33–37</sup>, we observed positive associations  
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38 between measures of adiposity and BP and hypertension after adjusting for covariates. The  
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40 consistency of the association underscores the significant contribution of increasing adiposity to  
41  
42 the prevalence of hypertension in young people. Moreover, the positive association between grip  
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44 strength with systolic BP z-score and hypertension upon adjustment in this study raises questions  
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46 about the benefits of strength training in children. The benefits of physical activity including  
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48 aerobic exercise in relation to hypertension remain clear; however, the benefits of strength  
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50 training in relation to hypertension risk, relative to the benefits of aerobic exercise, appear  
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52 questionable<sup>38</sup>. It is unclear what might be responsible for the positive effect observed between  
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3 grip strength and systolic BP z-score; however, findings from our study appear consistent with  
4 studies which have explored this association in Chinese<sup>39</sup> and American children<sup>40</sup>.  
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9 Despite the fact that the BP z-scores values take into consideration age, height and sex  
10 values, we opted to test for residual correlations by examining the independent effect of these  
11 variables on BP z-scores and hypertension values. The significant independent association  
12 observed between age, sex and height with both BP z-scores and hypertension suggest that the  
13 NHANES growth charts which are used in the development of the blood pressure tables might  
14 not be well-suited to the South Asian population. Consequently, given the high rates of  
15 hypertension in this population as documented both in this research study and those in other  
16 studies of South-Asian children, the development of growth charts that reflect the growth  
17 trajectory and the unique physiological changes which have been documented in South Asian  
18 (such as a higher body fat at similar BMI levels when compared to Caucasians) will be necessary  
19 to ensuring that the epidemiology of hypertension in South Asian children is captured.  
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35 The consistent association between adiposity and hypertension, including the higher  
36 prevalence of hypertension in this population, reinforces their connections through well-  
37 established mechanisms. Specifically, the South Asian phenotype of higher body fat<sup>7</sup>—especially  
38 the visceral type which has been identified in adults<sup>6</sup>—when compared to their Caucasian peers,  
39 could activate the formation of pro-inflammatory cytokines such as Interleukin 6 (IL-6) which  
40 results in physiological changes that could lead to endothelial and vascular dysfunction through  
41 the development of insulin resistance<sup>41</sup>, resulting in an increased predisposition for hypertension.  
42 The positive association between height and BP in this population could be explained by cerebral  
43 perfusion requirements where higher BP is needed in taller people to achieve optimal cerebral  
44 perfusion owing to hydrostatic pressure differences in taller and shorter individuals<sup>42</sup>. However,  
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3 more research in South Asian children is warranted to corroborate our findings given the  
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5 difference observed in direction of association in unadjusted and adjusted models.  
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9 The positive association we found between the child's perception of body image and BP  
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11 may be due to this variable mirroring children's weight status or conversely, a marker for a  
12  
13 graded increase in stress levels, owing to societal criticism of fatter body types, which could  
14  
15 have insidious effects for hypertension risk through its impact on the neuro-endocrine system<sup>43</sup>.  
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17 Additionally, a range of social and lifestyle variables were also found to be associated with BP z-  
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19 score in univariate analysis but disappeared upon adjustment. While results from univariate  
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21 associations may demonstrate links between risk factor and outcome, the disappearance of the  
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23 association upon adjustment for socio-demographic variables highlights the links between these  
24  
25 variables and suggests that the pathway linking these factors with BP might be interdependent.  
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31 The stepwise regression model shows that correlates from this study explained only about  
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33 30% of the variance of systolic BP z-score and 23% of the variability of diastolic BP z-scores. It  
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35 is possible that some of this unexplained variance might be explained by genetics, as it has been  
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37 suggested that about 30% to 60% of the variance in BP may be heritable<sup>44,45</sup>. Yet the lack of  
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39 association between parental hypertension and child BP in the subset of parents of participants  
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41 who provided this data would appear to contradict these findings for this population of South  
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43 Asian children. However, it is likely that the subset of parents of child participants who provided  
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45 this information might not be completely representative of the entire cohort, thereby biasing the  
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47 results. Still, even accounting for potential genetic contributions, a significant amount of the BP  
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49 variance remains unexplained. More research is needed to provide insight regarding the  
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51 contributory effects of other potential variables that might contribute to risk of elevated BP in  
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53 South Asian children.  
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3 Notably, null associations were also observed for certain variables in this study that have  
4 been found to be significantly associated with BP and hypertension in other child populations.  
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6 For example, parental history of hypertension, dietary factors (such as consumption of fruit and  
7  
8 vegetables) and exposure to second hand smoking have been linked in other studies to child BP  
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10 but had no significant impact in this study. This could be reflective of the potential biases  
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12 associated with using self-reports or may highlight how interactions between genes and  
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14 environment/lifestyle shape risk factor susceptibilities — underscoring the need for more ethnic-  
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16 based and ethnic comparison studies when exploring risk associations.  
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### 22 **Study Limitations**

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25 This study has limitations. First, although we sought to recruit a representative sample of  
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27 urban South Asian children, it was not a random sample. However, there is likely to be minimal  
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29 effect on the relationships between the ranges of risk factors evaluated in this study. Second, this  
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31 is a cross-sectional study and is therefore unable to provide insights into causal associations  
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33 between the risk factor variables and long term CVD risk in South Asian children. Third,  
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35 potential recall biases may have occurred as a result of using self-report data for some of the  
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37 variables including diet and physical activity measures. Last, the lack of data collection on sexual  
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39 maturity status could potential confound the study results obtained here. However, the  
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41 adjustment for age in this study, which acts as a proxy variable for sexual maturity might help  
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43 mitigate the bias. These limitations are in part addressed by strengths of this study which lies in  
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45 its large sample size of South Asian children and in the wide range of risk factors examined.  
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### 51 **Implications**

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3 Our findings underscore a range of factors that may contribute to risk of elevated BP and  
4 hypertension in South Asian children. Consequently, public health interventions such as those  
5 that emphasize prevention such as population-based health education and lifestyle modification  
6 that considers unique cultural contexts may provide significant potential in addressing the burden  
7 of hypertension in this population. There are also implications for clinical settings. Specifically,  
8 our findings suggest that while South Asian children may benefit from interventions aimed at  
9 reducing obesity to address the comparatively higher burden of hypertension in this population,  
10 there are certain sub-groups who could benefit from more targeted preventive interventions in  
11 primary care settings — such as males, children with increased adiposity, taller children, and  
12 children with increased heart rate, or children with a combination of these factors.  
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## 26 27 **CONCLUSION**

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30 In this group of South Asian children, we found univariate associations between a range  
31 of physiological, social and lifestyle factors with BP z-scores and hypertension. However, in  
32 multivariate analysis, physiological variables remained consistently associated with BP and  
33 hypertension, and provided the strongest explanatory effect for the variance in BP. Given the  
34 sequelae associated with elevated BP, including BP tracking from childhood into adulthood,  
35 these results provide evidence on modifiable risk factors that might be targeted by prevention  
36 strategies in primary care to reduce the burden of high BP and hypertension in South Asian  
37 children.  
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50 Rangarajan conceptualized the study, contributed to study design and reviewed the manuscript.  
51 Adeleke Fowokan conceptualized the study, drafted the initial manuscript, carried out statistical  
52 analysis and revised the manuscript. Dr. Waddell and Dr. Rosin contributed to the design of the  
53 study, reviewed and revised the manuscript.  
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3 All authors approved the final manuscript as submitted and agree to be accountable for all  
4 aspects of the work.  
5

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12

13 **Competing interests:** None declared  
14

15 **Ethics Approval:** Simon Fraser University Research Ethics Board (REB), Providence Health  
16 Care REB, and the Hamilton Integrated REB  
17

18 **Data sharing statement:** Raw data are held by the lead author of the study in accordance with  
19 ethics guidelines.  
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Table 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 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 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 (METmins/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*

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Table 2: Adjusted linear regression between multifactorial risk factors with systolic and diastolic BP z scores

	Systolic BP z score	Diastolic BP z score
Age <sup>a</sup>	-0.054 (-0.078, -0.029), p<0.001	-0.057 (-0.075, -0.039), p<0.001
Female sex (vs Male) <sup>b</sup>	-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 image	0.183 (0.128, 0.239), p<0.001	0.104 (0.064, 0.144), p<0.001
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	-0.127 (-0.484, 0.230), p=0.484	-0.063 (-0.336, 0.209), p=0.648

hypertension		
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  $\beta$  (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*

*<sup>a</sup>Age was adjusted for sex and father's education*

*<sup>b</sup>Sex was for adjusted for age and father's education*



Table 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 <sup>2</sup>
Systolic BP z-score	Child's age	-0.132	-0.202, -0.062	<0.001	0.294
	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	
Diastolic BP z-score	Child's age	-0.027	-0.048, -0.007	0.01	0.228
	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	

*BMI=body mass index, BP= blood pressure*

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3 Figure 1: Adjusted odds ratio for the association between the multifactorial variables with  
4 systolic hypertension  
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31 *Model adjusted for age, sex and father's education*

32 *Values presented are odds ratio (95% confidence intervals)*

33 *BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood*  
34 *pressure*

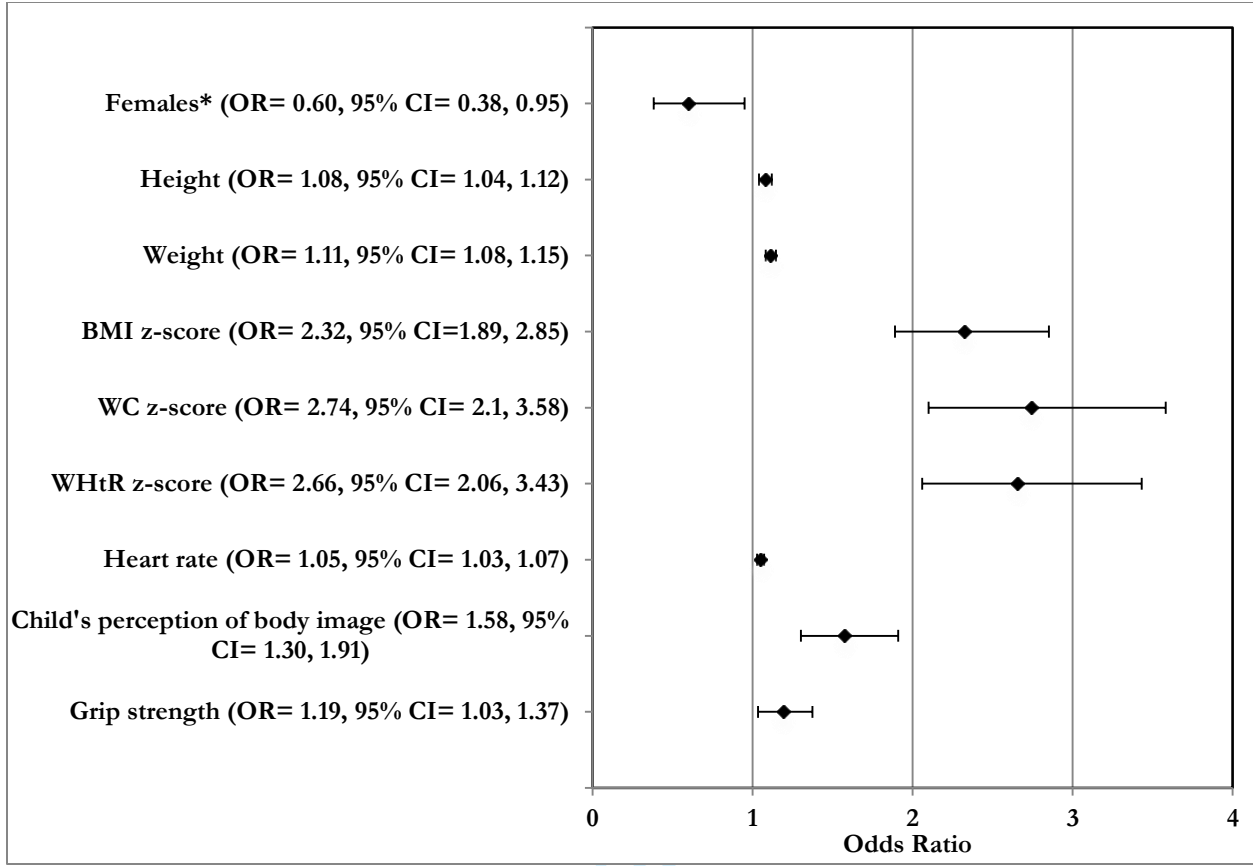
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31 *Model adjusted for age, sex and father's education*

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Model adjusted for age, sex and father's education

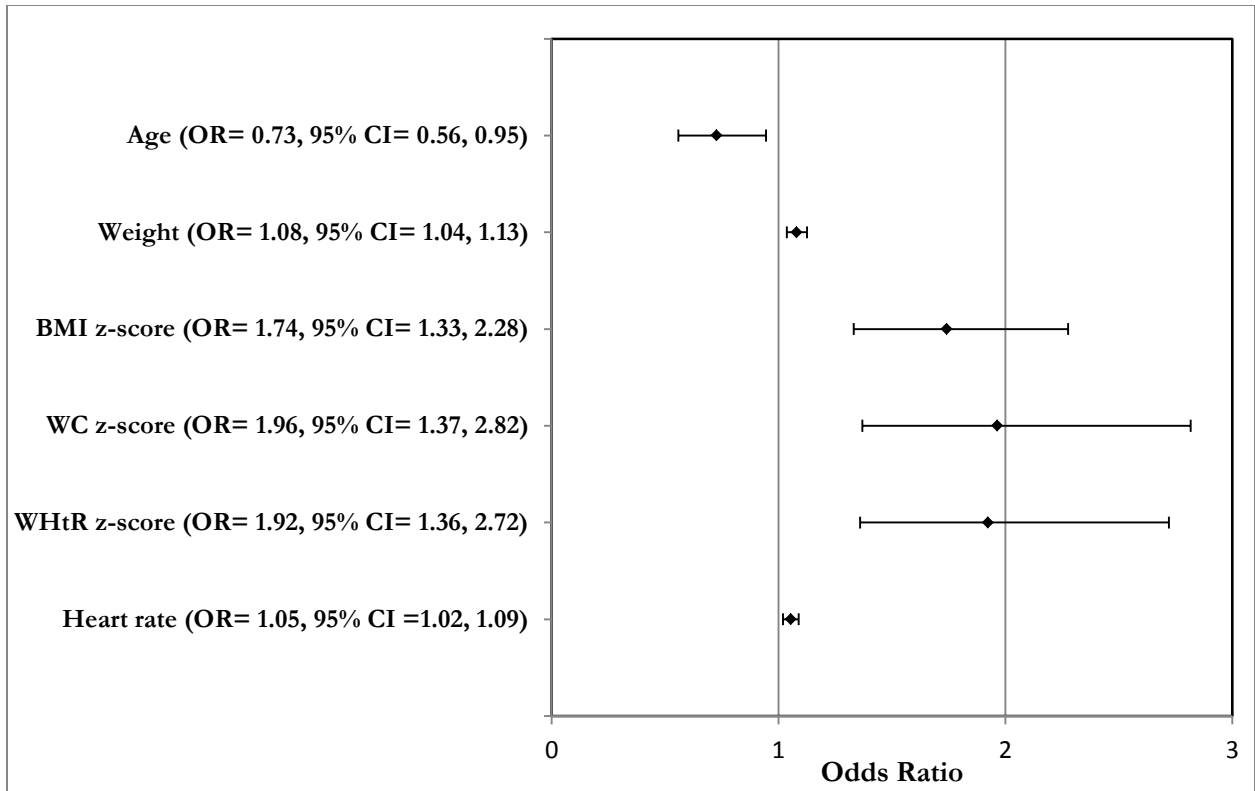
Values presented are odds ratio (95% confidence intervals)

BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure

\*compared to males

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*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*

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	N/A
	(c) Explain how missing data were addressed	7	
	(d) If applicable, describe analytical methods taking account of sampling strategy	N/A	
	(e) Describe any sensitivity analyses	N/A	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	24
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11

		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).



# BMJ Open

## Multifactorial correlates of blood pressure in South Asian children in Canada: a cross-sectional study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-027844.R1
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Date Submitted by the Author:	14-Jan-2019
Complete List of Authors:	Fowokan, Adeleke; Simon Fraser University, Department of Biomedical Physiology and Kinesiology Punthakee, Zubin; McMaster University, Medicine Waddell, Charlotte; Simon Fraser University, Faculty of Health Sciences Rosin, Miriam; Simon Fraser University, Department of Biomedical Physiology and Kinesiology Morrison, Katherine; McMaster University Department of Medicine Gupta, Milan; McMaster University Department of Medicine Rangarajan, Sumathy; Population Health Research Institute, Hamilton Health Sciences/McMaster University, Teo, Koon; Population Health Research Institute, Hamilton Health Sciences/McMaster University, Lear, Scott; Simon Fraser University, Faculty of Health Sciences
<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Paediatrics, Public health
Keywords:	Hypertension < CARDIOLOGY, PAEDIATRICS, EPIDEMIOLOGY

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Manuscripts

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3 **1 Multifactorial correlates of blood pressure in South Asian children in Canada: a cross-**  
4 **2 sectional study.**

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7 3 Fowokan AO, MPH<sup>1</sup>, Punthakee Z, MD<sup>2</sup>, Waddell C, MD<sup>5</sup>, Rosin M, PhD<sup>1</sup>, Morrison K, MD<sup>2</sup>,  
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24 13 **Running title: Correlates of blood pressure in South Asian children**

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28 15 **Keywords:** South Asian, children, hypertension, risk factors

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45  
46 24 Word count: 4402 words

## 1 **ABSTRACT**

2 **Objective:** In South Asian children, studies have documented higher blood pressure (BP) values  
3 and hypertension rates than in Caucasian children. To effectively address the burden of  
4 hypertension in this population, an understanding of associated factors is necessary. We sought  
5 to explore various correlates of BP and hypertension, and to identify the most important  
6 aggregate combination of correlates for BP in South Asian children.

7 **Design:** Cross-sectional study

8 **Setting:** Community-based recruitment in two Canadian cities (Hamilton and Surrey)

9 **Participants:** South Asian children (n=762) provided a range of physiological, behavioural and  
10 social variables. BP was assessed using an automated device. Body mass index (BMI), waist  
11 circumference (WC), waist-to-height ratio (WHtR) and BP were transformed to z-scores using  
12 published standards.

13 **Outcome measures:** Linear and logistic regression analyses were used to explore associations  
14 among the range of physiological, behavioural and social factors with BP z-scores and  
15 hypertension while stepwise regression was used to identify aggregate factors that provided  
16 explanatory capacity for systolic BP (SBP) and diastolic BP (DBP) z-scores.

17 **Results:** A range of variables were associated with BP z-score and hypertension in unadjusted  
18 analysis. Upon adjustment for confounders, the association between age, weight, BMI z-score,  
19 WC z-score, WHtR z-score, heart rate and child's perception of body image with SBP and DBP  
20 z-score (p<0.001 for all); sex with SBP z-score (p=0.004); height with SBP z-score (p<0.001);  
21 and grip strength with SBP z-score (p=0.007) remained. In stepwise regression, age, sex, BMI z-

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3 1 score, heart rate and weight accounted for 30% of the variance of SBP z-score, while age, BMI  
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5 2 z-score, heart rate and daily fast food intake accounted for 23% of the DBP z-score variance.  
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8 3 **Conclusion:** Our findings suggest that variables such as age, sex, height, adiposity, and heart rate  
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10 4 provide stronger explanatory capacity to BP variance and hypertension risk than other variables  
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13 5 in South Asian children.  
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3 **1 ARTICLE SUMMARY**  
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6 **2 Strengths and limitations of this study**  
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- 8
- 9 • The strengths of this study includes its large sample size of South Asian children and,
  - 10
  - 11 • Its examination of a wide range of physiological, behavioural and social risk factors in  
12 relation to BP z-scores and hypertension in South Asian children.
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  - 15 • Limitations of the study includes its cross-sectional design which limits the attribution of  
16 causality.  
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## 1 INTRODUCTION

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

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

15 In South Asian children, studies have demonstrated increased prevalence of hypertension  
16 or higher BP levels relative to other ethnic groups<sup>11,12</sup>. While there is evidence suggesting a  
17 disproportionately higher BP burden for South Asians, the exact factors implicated are relatively  
18 unclear. Given the fact that causes of high BP are known to be multifactorial<sup>8</sup>, it is important to  
19 understand the various risk factors that might be responsible for the increased risk of high BP in  
20 South Asian children in general. Using a range of multifactorial variables (i.e. variables across a  
21 range of different factors) that were identified in a recently published systematic review of  
22 children to be correlated with BP and hypertension in other children population groups<sup>13</sup>, this  
23 study therefore aims: 1) to explore the associations between physiological (factors relating to

1 biology), lifestyle (factors relating to behaviour) and social factors (factors relating to conditions  
2 in which people live, attend school, grow, and develop) and BP in South Asian children; and 2)  
3 to identify the most important aggregate correlates of BP in South Asian children.

## 4 **METHODS**

### 5 **Study Design**

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

### 13 **Recruitment**

14 Elementary school and high-school children (n= 762) were recruited using community-  
15 based methods in two Canadian cities (Brampton, Ontario and Surrey, British Columbia) by  
16 convenience sampling between 2012 and 2016. Letters were first sent to school boards to  
17 identify elementary schools with a high rate of South Asian enrolment. Once schools were  
18 identified, packages containing an invitation letter, a RICH-LEGACY study description and  
19 consent forms were sent to parents/guardians of children enrolled in the identified schools.  
20 Information stands were also placed at the participating elementary schools before and after  
21 school hours to reach out to parents with more information about the study. Additionally, the  
22 study was advertised through venues used by South Asian groups including newspapers, local

1 television stations, community centres, worship centres and festivals. Inclusion criteria included:  
2 children (in elementary or high school) having at least three grandparents of South Asian origin;  
3 and participants being able to provide consent (parents) and assent (children). Research assistants  
4 fluent in Hindi and Punjabi were responsible for participant recruitment and data collection. The  
5 research assistants who were involved in the measurements all undertook training together  
6 through simulator sessions and were retrained if variations in measurement protocol were  
7 observed by the research coordinator. This process was repeated for a few days to ensure  
8 accuracy and consistency amongst the research assistants in the assessment of the measurements  
9 collected in this study. In addition, written materials (including consent forms) were provided in  
10 English, Punjabi, Hindi and Urdu as needed.

### 11 **Participant Assessment**

12 Participants for the RICH-LEGACY study were assessed regarding socio-demographic  
13 variables including age, sex and parental education. In certain cases, parents or guardians helped  
14 complete certain sections of the child's questionnaire. Children's perception of body image was  
15 assessed using Stunkard's silhouettes, a rating scale from one to nine with increases related to  
16 increased silhouette size<sup>14</sup>, that assesses perception of size and body dissatisfaction. This figure  
17 rating scale has been shown to be a valid indicator of determining weight status in children<sup>15</sup>.  
18 Feeding practices were assessed using the childhood feeding questionnaire<sup>16</sup>. Exposure to  
19 bullying was assessed by asking participants if they had experienced bullying or violence at  
20 school. This variable was assessed because of its role as a known stressor in children and its  
21 possible impact on pathways known to be involved in BP regulation such as the hypothalamic-  
22 pituitary-adrenal (HPA) axis<sup>17</sup>. Additionally, level of acculturation was assessed using the  
23 Acculturation Rating Scale for Mexican Americans-II (ARSMA- II) adapted for use in South



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3 1 Asians by Stigler *et al*<sup>18</sup>. This scale assesses an individual's identification with their heritage  
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5 2 based on different domains including language preferences, media preferences, and preferences  
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7 3 regarding food and other consumer goods using 24 questions<sup>18</sup>. The adapted questionnaire is  
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9 4 grouped into two scales: the Western scale and the traditional scale. The traditional acculturation  
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11 5 score measures children's acceptance of traditional Indian cultural attributes while the  
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13 6 Westernized acculturation score measures the degree to which South Asian children identify with  
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15 7 Western culture.  
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20 8 Participants completed a semi-quantitative food frequency questionnaire (FFQ) that  
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22 9 assessed intake of fruits and vegetables and fast foods consumption. The FFQ was adapted from  
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24 10 the INTERHEART FFQ, which was validated in an international cohort that included South  
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26 11 Asians<sup>19</sup>. Physical activity was assessed using a standardized questionnaire that quantified sports  
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28 12 and other activities including leisure, household chores and sedentary factors (screen time and  
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30 13 homework) during school and outside of school over the past month. All activities were then  
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32 14 expressed as metabolic-equivalent-of-task (MET) minutes. Self-reported exposure to second-  
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34 15 hand smoke was assessed to characterize children's passive exposure to smoking and defined as  
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36 16 a minimum of five consecutive minutes during which inhalation of other people's smoke occurs.  
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38 17 Hand-grip strength, a measure of muscular strength, was measured on the non-dominant hand by  
39  
40 18 study personnel with a Jamar dynamometer utilizing standardized protocol<sup>20</sup>.  
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### 46 19 **Anthropometric Characteristics**

47  
48 20 Height was measured to the nearest 0.1 cm using a right angle triangle and a calibrated  
49  
50 21 wall mounted scale. Weight was measured to the nearest 0.1 kg with the subject in light clothing  
51  
52 22 using an electronic scale. Body mass index (BMI) was first calculated from weight in kilograms  
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1 divided by height in meters squared before being converted to z-scores using WHO growth  
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1 divided by height in meters squared before being converted to z-scores using WHO growth  
2 references for young people aged 5-19 years<sup>21</sup>.

3           Waist circumference (WC) was recorded in centimetres as the average of two measures  
4 taken halfway between the lower rib margin and the iliac crest against the skin following a  
5 normal expiration. Waist circumference was assessed using non-stretching measuring tape by  
6 trained team members. Waist-to-height ratio (WtHR) was then calculated by dividing waist  
7 circumference by height. Both WC and WtHR were transformed to z scores using published  
8 lambda-mu-sigma (LMS) values for age and sex based on the third US National Health and  
9 Nutrition Examination Survey (NHANES III)<sup>22</sup>. Transforming the anthropometric measures to z-  
10 scores allowed for the standardized comparisons across populations of children of similar ages  
11 and sex.

## 12 **Blood Pressure and Heart Rate**

13           Blood pressure and heart rate were measured in the left arm using the Omron HEM-  
14 711DLX automated blood pressure monitor with appropriate sized cuffs following 10 minutes of  
15 seated rest. Three BP and heart rate measures were taken over a 10-minute period and the  
16 average of the three was recorded. Subsequently, BP was transformed to standard deviation  
17 scores and percentiles adjusted for age, sex and height according to the fourth National High  
18 Blood Pressure Education Program (NHBPEP) working group in children and adolescents<sup>23</sup>.  
19 Systolic and diastolic hypertension were defined using the NHBPEP recommendations as  
20 average systolic blood pressure or diastolic blood pressure equal to or greater than the 95<sup>th</sup>  
21 percentile for sex, age and height.

## 22 **Parental Variables**

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2  
3 1 Parents of the children recruited for this study provided information on parental education  
4  
5 2 (father's and mother's education). In a smaller subset of the South Asian children (n=271),  
6  
7 3 parental history of hypertension (yes or no) was assessed in order to explore the potential impact  
8  
9 4 of heritable factors on children's BP z-scores and hypertension. Father's education was used as a  
10  
11 5 proxy variable for socioeconomic status in this study. Fathers' education levels were categorized  
12  
13 6 as: those with no formal education; those with primary/secondary school education; those with a  
14  
15 7 trade school degree/diploma; and those with a college or university degree. Parent's smoking  
16  
17 8 status was self-reported and categorized as non-smoker, former smoker, or current smoker.  
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## 22 9 **Statistical Analysis**

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24  
25 10 All continuous variables were examined using P-P plots and found to be normally  
26  
27 11 distributed. For descriptive analysis, continuous variables were presented as means and standard  
28  
29 12 deviations while categorical variables were reported as counts and percentages. Independent t-  
30  
31 13 test analysis was used to assess sex differences in continuous variables, while chi-square tests  
32  
33 14 were used to assess sex differences in categorical variables.  
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38 15 To explore the associations among the range of physiological, behavioural and  
39  
40 16 sociodemographic variables with systolic and diastolic BP, unadjusted linear regression was  
41  
42 17 used. These models were then adjusted for potential confounding effect of child age, sex and  
43  
44 18 father's education. These confounders were selected based on their well –documented  
45  
46 19 independent associations with the outcome variable in research studies<sup>11,13</sup>. Although, the  
47  
48 20 conversion of to z-scores provides age and sex adjusted data, we chose to still include age and  
49  
50 21 sex as confounders to adjust for potential residual effects unaccounted for by the reference chart  
51  
52 22 used in this study. Similarly, unadjusted and adjusted (age, sex and father's education) logistic  
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1 regression analysis was used to explore clinically-relevant associations among the multifactorial  
2 variables with systolic and diastolic hypertension. While age and sex were identified as potential  
3 confounders in the association between the other variables assessed in this study with BP and  
4 hypertension, we also wanted to examine their independent associations with BP and  
5 hypertension. To do this, they were each removed from the list of confounders we adjusted for  
6 when exploring their effect on BP z-scores and hypertension (i.e., sex was adjusted for age and  
7 father's education, while age was adjusted for sex and father's education.)

8 To address the second study objective, stepwise multiple linear regression analyses were  
9 used to identify the combination of risk factors that best explained the variance in BP in South  
10 Asian children. The stepwise regression method enables the identification of the aggregate  
11 combination of correlates that has the highest contributory effect to the outcome variable.  
12 Specifically, for this analysis, we utilized the backward method to select the list of multifactorial  
13 correlates that provide significant contribution to the outcome (systolic and diastolic BP z-  
14 scores) using an entry criterion of  $p < 0.05$  and a removal criterion of  $p > 0.10$ . The specific list of  
15 correlates (age, sex, height, weight, heart rate, BMI z-score, WC z-score, WHtR z-score, parental  
16 history of hypertension, parental education, exposure to bullying and violence, traditional and  
17 western acculturation scores, physical activity in school and outside school, dietary variables and  
18 second-hand smoking) considered for introduction in the backward stepwise regression model  
19 were chosen *a priori* based on literature evidence<sup>13</sup> and whether they had a p value  $< 0.05$  in  
20 unadjusted analysis. Using the aforementioned criteria, the following variables were considered  
21 in step-wise regression analysis: age, sex, height, weight, BMI z-score, WC z-score, WHtR z-  
22 score, heart rate, western acculturation score, child's perception of body image, and grip  
23 strength. In addition to these variables, father's education, daily intake of fast foods and total

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2  
3 1 daily intake were considered in diastolic BP z-score models. The adjusted R squared value for  
4  
5 2 each model provides the combined contribution of the variables in the model to the variance in  
6  
7 3 BP z-scores. The full list of variables initially identified from literature search were also  
8  
9 4 considered in logistic regression models with hypertension. Statistical analysis was done using  
10  
11 5 SPSS version 24.0. P values <0.05 were considered statistically significant. This study was  
12  
13 6 written in line with the Strengthening the Reporting of Observational studies in Epidemiology  
14  
15 7 (STROBE) guidelines<sup>24</sup>

## 8 **Patient and Public Involvement**

9 The research questions and outcome measures in this study were chosen by this team of  
10  
11 researchers and clinicians with extensive experience working with the South Asian population to  
12  
13 better understand the potential health risks faced by South Asian children. No patients were  
14  
15 involved in setting the research question in development of the research question or study design.  
16  
17 There are currently no plans to disseminate the results of this research study to study participants  
18  
19 or to the relevant patient population.

## 20 **RESULTS**

21 This study included 360 boys (47%) and 402 girls ranging from 5.8 to 17.0 years (mean  
22  
23 age  $9.5 \pm 3.0$  years), with no statistically significant difference observed for age by sex (table 1).  
24  
25 The prevalence of systolic hypertension in this population was 12%. South Asian boys were  
26  
27 more physically active outside school than girls ( $p=0.04$ ); higher WC z-score ( $p<0.001$ ); higher  
28  
29 WHtR z-score ( $p=0.02$ ); lower heart rate ( $p=0.047$ ); higher systolic BP z-scores ( $p=0.001$ );  
30  
31 higher prevalence of systolic hypertension ( $p=0.01$ ); had lower traditional acculturation score  
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33 ( $p=0.02$ ); and significantly higher exposure to bullying and violence at school ( $p=0.025$ ).  
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## 1 Correlates of Systolic BP and Systolic Hypertension

2 In unadjusted linear regression analysis with systolic BP z-scores, weight (kg) ( $\beta = 0.005$ ,  
3 95% CI= 0.001, 0.01,  $p=0.022$ ), BMI z-score ( $\beta = 0.289$ , 95% CI= 0.246, 0.333,  $p<0.001$ ), WC z-  
4 score ( $\beta = 0.266$ , 95% CI= 0.213, 0.319,  $p<0.001$ ), WHtR z-score ( $\beta = 0.271$ , 95% CI= 0.219,  
5 0.324,  $p<0.001$ ), heart rate (beats per minute) ( $\beta = 0.019$ , 95% CI= 0.015, 0.023,  $p<0.001$ ), and  
6 the child's perception of their body image (using Stunkard's silhouettes) ( $\beta = 0.136$ , 95% CI=  
7 0.083, 0.189,  $p<0.001$ ) were found to be positively associated with systolic BP z-score. In  
8 contrast, we found that compared to male sex, female sex had lower systolic BP z-score ( $\beta = -$   
9 0.246, 95% CI= -0.385, -0.108,  $p<0.001$ ). Similarly, age (years) ( $\beta = -0.060$ , 95% CI= -0.084, -  
10 0.037,  $p<0.001$ ), children's western acculturation score ( $\beta = -0.021$ , 95% CI= -0.036, -0.006,  
11  $p=0.007$ ) and height (cm) ( $\beta = -0.006$ , 95% CI= -0.010, -0.002,  $p=0.007$ ) were negatively  
12 associated with systolic BP z-score. After adjustment for confounders, the association between  
13 western acculturation attenuated and became non-significant, while the association observed  
14 between height and systolic BP z-score became positive. Associations between children's grip  
15 strength and daily physical activity in school with systolic BP z-score also became significant  
16 upon adjustment (table 2).

17 In stepwise regression analysis, the combination of age, sex, BMI z-score, heart rate and  
18 weight were observed to be the most important correlates of systolic BP z-score, accounting for  
19 30% of the systolic BP z-score variance of South Asian children (Table 3).

20 In unadjusted logistic regression analysis, female sex was associated with lower odds of  
21 developing systolic hypertension (odds ratio (OR) = 0.56, 95% CI= 0.36, 0.87,  $p=0.011$ ).

22 Associations were also observed with weight (kg) and systolic hypertension (OR= 1.02, 95%

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3 1 CI= 1.01, 1.04,  $p<0.001$ ), BMI z-score and systolic hypertension (OR= 2.22, 95% CI= 1.84,  
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5 2 2.68,  $p<0.001$ ), WC z-score and systolic hypertension (OR= 2.65, 95% CI= 2.06, 3.43,  $p<0.001$ )  
6  
7 3 and WHtR z-score and systolic hypertension (OR= 2.47, 95% CI= 1.95, 3.13,  $p<0.001$ ).  
8  
9 4 Similarly, associations were observed between heart rate (beats per minute) and systolic  
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11 5 hypertension (OR=1.04, 95% CI= 1.02, 1.06,  $p<0.001$ ), child's perception of body image and  
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13 6 systolic hypertension (OR= 1.50, 95% CI= 1.25, 1.79,  $p<0.001$ ) and western acculturation score  
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15 7 with systolic hypertension (OR= 0.95, 95% CI=0.90, 1.00,  $p=0.03$ ). Upon adjustment for  
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17 8 confounders, the associations between western acculturation score and systolic hypertension  
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19 9 attenuated and became non-significant. The association between grip strength and systolic  
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21 10 hypertension became significant upon adjustment (Figure 1).  
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### 27 **Correlates of Diastolic BP and Diastolic Hypertension**

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29  
30 12 In unadjusted linear regression analysis of multifactorial variables with diastolic BP z-  
31  
32 13 score, negative associations with diastolic BP z-score were observed between age (years) ( $\beta= -$   
33  
34 14 0.061,  $p<0.001$ ), height (cm) ( $\beta= -0.009$ ,  $p<0.001$ ), western acculturation score ( $\beta= -0.018$ ,  
35  
36 15  $p=0.007$ ), fathers' level of education ( $\beta= -0.054$ ,  $p=0.047$ ), total daily food intake ( $\beta= -0.016$ ,  
37  
38 16  $p=0.005$ ), fast foods ( $\beta= -0.065$ ,  $p=0.048$ ) and grip strength (kg) ( $\beta= -0.019$ ,  $p<0.001$ ).  
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40  
41 17 Conversely, significant positive associations with diastolic BP z-score were observed between  
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43 18 heart rate ( $\beta= 0.018$ ,  $p<0.001$ ), BMI z-score ( $\beta= 0.156$ ,  $p<0.001$ ), WC z-score ( $\beta= 0.120$ ,  
44  
45 19  $p<0.001$ ), WHtR z-score ( $\beta= 0.128$ ,  $p<0.001$ ), and children's perception of their body image  
46  
47 20 (using Stunkard's silhouettes) ( $\beta= 0.053$ ,  $p=0.007$ ). After adjustment for confounders the  
48  
49 21 association between height, western acculturation score, father's level of education, total daily  
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51 22 food intake, fast food consumption and grip strength attenuated and became non-significant  
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53 23 (Table 2).  
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3 1 In stepwise regression analysis, the combination of age, BMI z-score, heart rate and daily  
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5 2 intake of fast foods were observed to be the most important aggregate correlates of diastolic BP  
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7 3 z-score, accounting for 23% of the diastolic BP z-score variance of South Asian children (Table  
8  
9 4 3).

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13 5 In unadjusted logistic regression analysis, associations were observed between age  
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15 6 (years) (OR= 0.71, 95% CI= 0.55, 0.92, p=0.01), height (OR= 0.97, 95% CI= 0.94, 1.00,  
16  
17 7 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%  
18  
19 8 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  
20  
21 9 (beats per minute) (OR=1.06, 95% CI= 1.03, 1.10, p<0.001) and grip strength (kg) (OR= 0.92,  
22  
23 10 95% CI= 0.86, 0.99, p=0.024) with diastolic hypertension. Upon adjustment for confounders, the  
24  
25 11 association between height, grip strength and diastolic hypertension attenuated and became non-  
26  
27 12 significant (Figure 2).

## 13 **DISCUSSION**

14  
15 14 This study provides information on a range of correlates of systolic and diastolic BP z-  
16  
17 15 scores in a population of South Asian children. While results from unadjusted models highlight  
18  
19 16 the presence of a multifactorial relationship for BP and hypertension, the disappearance of most  
20  
21 17 of the social and lifestyle risk factors upon adjustment highlights the contribution of variables  
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23 18 such as age, sex, adiposity, height, heart rate, and grip strength to the risk of elevated BP and  
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25 19 hypertension in South Asian children.

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51 20 It is well documented that the burden of hypertension has precipitously increased in the  
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53 21 pediatric population<sup>25</sup>. In addition, some studies have documented higher prevalence of  
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55 22 hypertension in certain ethnic groups such as South Asians<sup>11</sup>. Although our sample was based on  
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3 1 convenience and non-representative given that sampling was restricted to two Canadian cities,  
4  
5 2 the prevalence of hypertension in our study at 12% is consistent with age, sex and height  
6  
7 3 adjusted estimates from Jafar *et al*<sup>11</sup> using a nationally-representative survey of Pakistani  
8  
9 4 children age 5 to 14 years, but higher than 5.2% prevalence from one cross-sectional study of  
10  
11 5 Indian children ages 5 to 12 years<sup>26</sup>. Our estimates also appear higher than estimates from  
12  
13 6 Canadian children ages 6 to 19 years where 4% of children were said to have hypertension and  
14  
15 7 prehypertension<sup>27</sup>. When stratified by sex, we found significantly higher rates were observed for  
16  
17 8 boys at 15% compared to girls at 9%. This is consistent with results from studies in other  
18  
19 9 children which have reported higher hypertension prevalence in boys<sup>28,29</sup>, and results from  
20  
21 10 regression analysis which found female sex to be associated with lower odds of hypertension.  
22  
23 11 This risk differential has been attributed to the presence of an anti-inflammatory immune profile  
24  
25 12 in females and pro-inflammatory profile in males<sup>30</sup> — underscoring the potential for intervention  
26  
27 13 efforts aimed at addressing sex-based disparities.

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34 14 Consistent with research conducted in South Asian children<sup>11,31</sup> and research conducted  
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36 15 in other childhood populations of different ethnicities<sup>28,32–36</sup>, we observed positive associations  
37  
38 16 between measures of adiposity and BP and hypertension after adjusting for covariates. The  
39  
40 17 consistency of the association observed across the range of adiposity metrics assessed  
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42 18 underscores the significant contribution of increasing adiposity to the prevalence of hypertension  
43  
44 19 in South Asian children. Moreover, the positive association between grip strength (a measure of  
45  
46 20 muscle strength) with systolic BP z-score and hypertension upon adjustment in this study raises  
47  
48 21 questions about the benefits of strength training in children. The benefits of physical activity  
49  
50 22 including aerobic exercise in relation to hypertension remain clear; however, the benefits of  
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52 23 strength training in relation to hypertension risk, relative to the benefits of aerobic exercise,  
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3 1 appear questionable<sup>37</sup>. It is unclear what might be responsible for the positive effect observed  
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5 2 between grip strength and systolic BP z-score; however, findings from our study appear  
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7 3 consistent with studies which have explored this association in Chinese<sup>38</sup> and American  
8  
9 4 children<sup>39</sup>.

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13 5 The consistent association between adiposity and hypertension, including the higher  
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15 6 prevalence of hypertension in this population, reinforces their connections through a range of  
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17 7 complex mechanistic pathways. Some of these pathways involve the activation of the renin-  
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19 8 angiotensin-aldosterone system (RAAS) or sympathetic nervous system. Specifically, the South  
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21 9 Asian phenotype of higher body fat<sup>7</sup>—especially the visceral type which has been identified in  
22  
23 10 adults<sup>6</sup>—when compared to their Caucasian peers, could activate the formation of pro-  
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25 11 inflammatory cytokines such as Interleukin 6 (IL-6) which results in physiological changes that  
26  
27 12 could lead to endothelial and vascular dysfunction through the development of insulin  
28  
29 13 resistance<sup>40</sup>, resulting in an increased predisposition for hypertension. The positive association  
30  
31 14 between height and BP in this population could be explained by cerebral perfusion requirements  
32  
33 15 where higher BP is needed in taller people to achieve optimal cerebral perfusion owing to  
34  
35 16 hydrostatic pressure differences in taller and shorter individuals<sup>41</sup>. However, more research in  
36  
37 17 South Asian children is warranted to corroborate our findings given the difference observed in  
38  
39 18 direction of association in unadjusted and adjusted models.  
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46 19 The positive association we found between the child's perception of body image and BP  
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48 20 may be due to this variable mirroring children's weight status or conversely, a marker for a  
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50 21 graded increase in stress levels, owing to societal criticism of fatter body types, which could  
51  
52 22 have insidious effects for hypertension risk through its impact on the neuro-endocrine system<sup>42</sup>.  
53  
54 23 Additionally, a range of social and lifestyle variables were also found to be associated with BP z-  
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1 score in unadjusted analysis but became non-significant upon adjustment for confounders. While  
2 results from unadjusted associations may demonstrate links between risk factor and outcome, the  
3 disappearance of the association upon adjustment for socio-demographic variables highlights the  
4 links between these variables and suggests that the pathway linking these factors with BP might  
5 be interdependent.

6 The stepwise regression model shows that correlates from this study explained only about  
7 30% of the variance of systolic BP z-score and 23% of the variability of diastolic BP z-scores. It  
8 is possible that some of this unexplained variance might be explained by genetics, as it has been  
9 suggested that about 30% to 60% of the variance in BP may be heritable<sup>43,44</sup>. Yet the lack of  
10 association between parental hypertension and child BP in the subset of parents of participants  
11 who provided this data would appear to contradict these findings for this population of South  
12 Asian children. However, it is likely that the subset of parents of child participants who provided  
13 this information might not be completely representative of the entire cohort, thereby biasing the  
14 results. Still, even accounting for potential genetic contributions, a significant amount of the BP  
15 variance remains unexplained. More research is needed to provide insight regarding the  
16 contributory effects of other potential variables that might contribute to risk of elevated BP in  
17 South Asian children.

18 Notably, null associations were also observed for certain variables in this study that have  
19 been found to be significantly associated with BP and hypertension in other child populations.  
20 For example, parental history of hypertension, dietary factors (such as consumption of fruit and  
21 vegetables) and exposure to second hand smoking have been linked in other studies to child BP  
22 but had no significant impact in this study. This could be reflective of the potential biases  
23 associated with using self-reports or may highlight how interactions between genes and

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3 1 environment/lifestyle shape risk factor susceptibilities — underscoring the need for more ethnic-  
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5 2 based and ethnic comparison studies when exploring risk associations.  
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### 8 9 3 **Study Limitations**

10  
11 4 This study has limitations. First, although we sought to recruit a representative sample of  
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13 5 urban South Asian children, it was not a random sample. However, there is likely to be minimal  
14  
15 6 effect on the relationships between the ranges of risk factors evaluated in this study. Second, this  
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17 7 is a cross-sectional study and is therefore unable to provide insights into causal associations  
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19 8 between the risk factor variables and long term CVD risk in South Asian children. Third,  
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21 9 potential recall biases may have occurred as a result of using self-report data for some of the  
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23 10 variables including diet and physical activity measures. Fourth, the use of father's education as a  
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25 11 measure of socioeconomic status pose limitations. Variables like household income would have  
26  
27 12 been preferred, however only a subset of participants provided data on household income, thus  
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29 13 its use would have excluded a significant portion of children in this study. However, as a means  
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31 14 to confirm the results, we separately adjusted for mother's education and no deviation in study  
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33 15 results was observed. Last, the lack of data collection on sexual maturity status could potential  
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35 16 confound the study results obtained here. However, the adjustment for age in this study, which  
36  
37 17 acts as a proxy variable for sexual maturity might help mitigate the bias. These limitations are in  
38  
39 18 part addressed by strengths of this study which lies in its large sample size of South Asian  
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41 19 children and in the wide range of risk factors examined.  
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### 49 20 **Implications**

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52 21 Our findings underscore a range of factors that may contribute to risk of elevated BP and  
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54 22 hypertension in South Asian children. Consequently, public health interventions such as those  
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1 that emphasize prevention such as population-based health education and lifestyle modification  
2 that considers unique cultural contexts may provide significant potential in addressing the burden  
3 of hypertension in this population. There are also implications for clinical settings. Specifically,  
4 our findings suggest that while South Asian children may benefit from interventions aimed at  
5 reducing obesity to address the comparatively higher burden of hypertension in this population,  
6 there are certain sub-groups who could benefit from more targeted preventive interventions in  
7 primary care settings — such as males, children with increased adiposity, taller children, and  
8 children with increased heart rate, or children with a combination of these factors.

## 9 CONCLUSION

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

18 **Author contributions:** Dr. Scott, Dr. Punthakee, Dr. Morrison, Dr. Gupta, Dr. Teo and Sumathy  
19 Rangarajan conceptualized the study, contributed to study design and reviewed the manuscript.  
20 Adeleke Fowokan conceptualized the study, drafted the initial manuscript, carried out statistical  
21 analysis and revised the manuscript. Dr. Waddell and Dr. Rosin contributed to the design of the  
22 study, reviewed and revised the manuscript.

23 All authors approved the final manuscript as submitted and agree to be accountable for all  
24 aspects of the work.

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8  
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10  
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12 7 Care REB, and the Hamilton Integrated REB

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14 8 **Data sharing statement:** Raw data are held by the lead author of the study in accordance with  
15 9 ethics guidelines.

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1 Table 1: Sociodemographic, anthropometric, risk factor characteristics of South Asian children  
 2 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 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 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 (METmins/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

1 \*Exposure defined as a minimum of five consecutive minutes during which inhalation of other  
 2 people's smoke occurs  
 3 BP=Blood pressure, BMI=body mass index, WC= waist circumference, WHtR= waist to height  
 4 ratio, SBP= systolic blood pressure, DBP= diastolic blood pressure  
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1 Table 2: Adjusted linear regression between multifactorial risk factors with systolic and diastolic  
 2 BP z scores

	Systolic BP z score	Diastolic BP z score
Age <sup>a</sup>	-0.054 (-0.078, -0.029), p<0.001	-0.057 (-0.075, -0.039), p<0.001
Female sex (vs Male) <sup>b</sup>	-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 image	0.183 (0.128, 0.239), p<0.001	0.104 (0.064, 0.144), p<0.001
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	-0.127 (-0.484, 0.230), p=0.484	-0.063 (-0.336, 0.209), p=0.648

hypertension		
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

1 *Model adjusted for age, sex and father's education*

2 *Values presented are  $\beta$  (95% confidence intervals), and p values*

3 *BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure, MET=Metabolic equivalent of task*

4 *<sup>a</sup>Age was adjusted for sex and father's education*

5 *<sup>b</sup>Sex was for adjusted for age and father's education*

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1 Table 3: Stepwise linear regression analysis showing the aggregate correlates of BP z-score in  
 2 South Asian children

Stepwise multiple linear regression models					
	Variable	B	95%	P value	Adjusted R <sup>2</sup>
Systolic BP z-score	Child's age	-0.132	-0.202, -0.062	<0.001	0.294
	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	
Diastolic BP z-score	Child's age	-0.027	-0.048, -0.007	0.01	0.228
	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	

3 *BMI=body mass index, BP= blood pressure*

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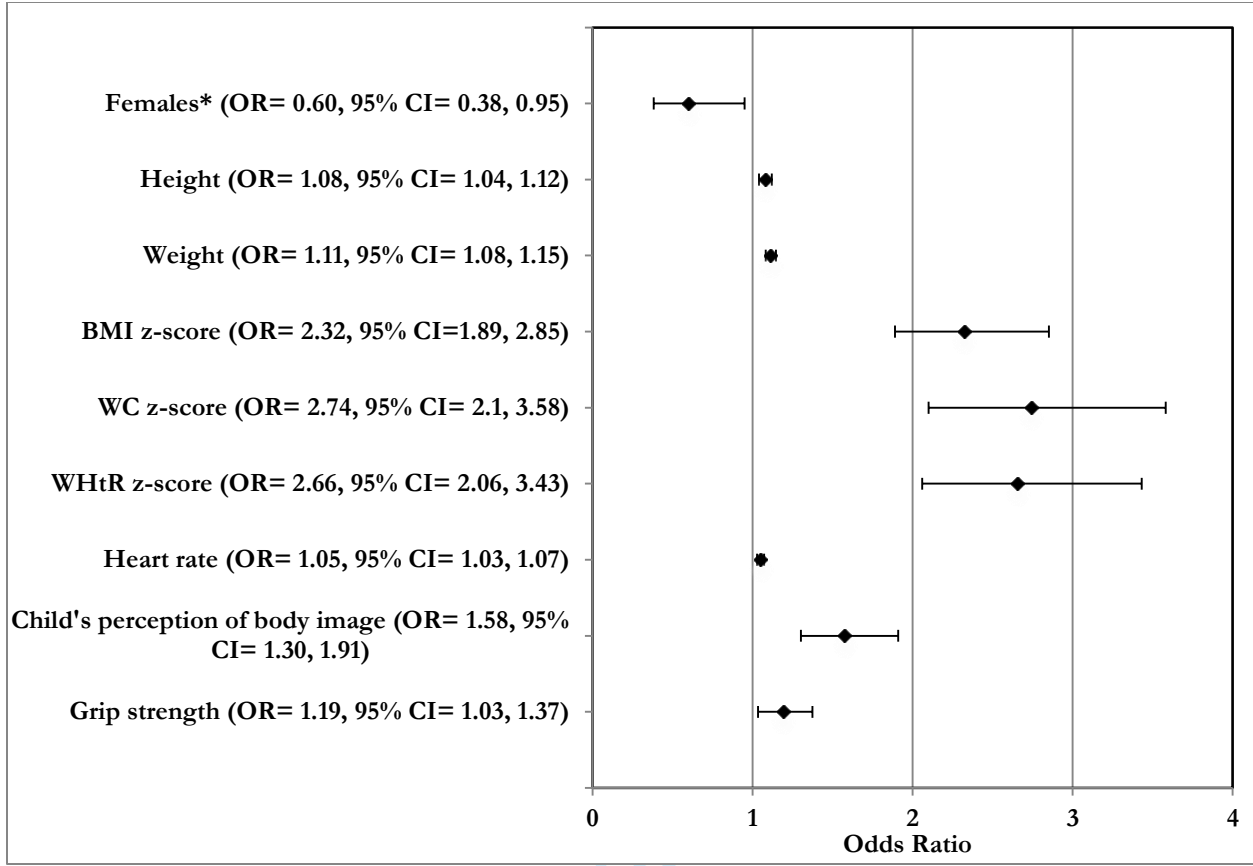
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3 1 Figure 1: Adjusted odds ratio for the association between the multifactorial variables with  
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1 Figure 2: Adjusted odds ratio for the association between the multifactorial variables with  
2 diastolic hypertension

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Model adjusted for age, sex and father's education

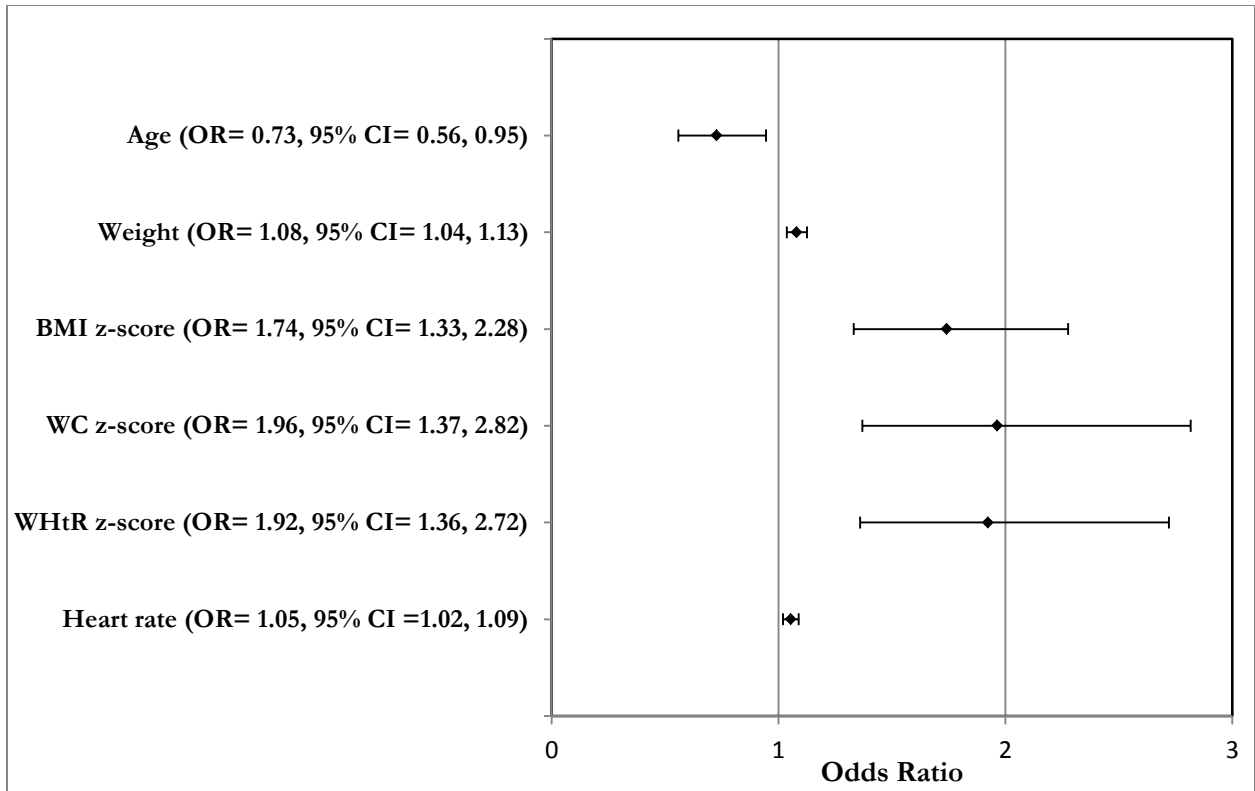
Values presented are odds ratio (95% confidence intervals)

BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure

\*compared to males

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*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*

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	N/A
	(c) Explain how missing data were addressed	7	
	(d) If applicable, describe analytical methods taking account of sampling strategy	N/A	
	(e) Describe any sensitivity analyses	N/A	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	24
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11

		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Multifactorial correlates of blood pressure in South Asian children in Canada: a cross-sectional study

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3 **1 Multifactorial correlates of blood pressure in South Asian children in Canada: a cross-**  
4 **2 sectional study.**

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23  
24 13 **Running title: Correlates of blood pressure in South Asian children**

25  
26 14

27  
28 15 **Keywords:** South Asian, children, hypertension, risk factors

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30 16

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45  
46 24 Word count: 4402 words

## 1 ABSTRACT

2 **Objective:** We sought to explore various correlates of BP and hypertension, and to identify the  
3 most important aggregate combination of correlates for BP in South Asian children.

4 **Design:** Cross-sectional study

5 **Setting:** Community-based recruitment in two Canadian cities

6 **Participants:** South Asian children (n=762) provided a range of physiological, lifestyle and  
7 social variables. BP was assessed using an automated device. Body mass index (BMI), waist  
8 circumference (WC), waist-to-height ratio (WHtR) and BP were transformed to z-scores using  
9 published standards.

10 **Outcome measures:** Linear and logistic regression analyses were used to explore associations  
11 between the range of variables with BP z-scores and hypertension while stepwise regression was  
12 used to identify aggregate factors that provided explanatory capacity for systolic BP (SBP) and  
13 diastolic BP (DBP) z-scores.

14 **Results:** A range of variables were associated with BP z-score and hypertension in unadjusted  
15 analysis. Upon adjustment for confounders, the association between age ( $\beta = -0.054$ , 95% CI -  
16 0.078, 0.029, female sex ( $\beta = -0.208$ , 95% CI= -0.350, -0.067), height ( $\beta = 0.022$ , 95% CI= 0.011,  
17 0.033), weight ( $\beta = 0.047$ , 95% CI= 0.040, 0.055) BMI z-score ( $\beta = 0.292$ , 95% CI 0.249, 0.336),  
18 WC z-score ( $\beta = 0.273$ , 95% CI= 0.219, 0.326), WHtR z-score ( $\beta = 0.289$ , 95% CI= 0.236,  
19 0.342), heart rate ( $\beta = 0.016$ , 95% CI= 0.010, 0.022), child's perception of body image ( $\beta = 0.183$ ,  
20 95% CI= 0.128, 0.239) and grip strength ( $\beta = 0.025$ , 95% CI= 0.007, 0.043) with SBP z-score  
21 remained. In stepwise regression, age, sex, BMI z-score, heart rate and weight accounted for

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3 1 30% of the variance of SBP z-score, while age, BMI z-score, heart rate and daily fast food intake  
4  
5 2 accounted for 23% of the DBP z-score variance.  
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8 3 **Conclusion:** Our findings suggest that variables such as age, sex, height, adiposity, and heart rate  
9  
10 4 provide stronger explanatory capacity to BP variance and hypertension risk than other variables  
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13 5 in South Asian children.  
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For peer review only

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3 **1 ARTICLE SUMMARY**  
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6 **2 Strengths and limitations of this study**  
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- 8  
9 • The strengths of this study includes its large sample size of South Asian children and,  
10  
11 • Its examination of a wide range of physiological, lifestyle and social risk factors in  
12  
13 relation to BP z-scores and hypertension in South Asian children.  
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15 • Limitations of the study includes its cross-sectional design which limits the attribution of  
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17 causality.  
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## 1 INTRODUCTION

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

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

15 In South Asian children, studies have demonstrated increased prevalence of hypertension  
16 or higher BP levels relative to other ethnic groups<sup>11,12</sup>. While there is evidence suggesting a  
17 disproportionately higher BP burden for South Asians, the exact factors implicated are relatively  
18 unclear. Given the fact that causes of high BP are known to be multifactorial<sup>8</sup>, it is important to  
19 understand the various risk factors that might be responsible for the increased risk of high BP in  
20 South Asian children in general. Using a range of multifactorial variables (i.e. variables across a  
21 range of different factors) that were identified in a recently published systematic review of  
22 children to be correlated with BP and hypertension in other children population groups<sup>13</sup>, this  
23 study therefore aims: 1) to explore the associations between physiological (factors relating to

1 biology), lifestyle (factors relating to behaviour) and social factors (factors relating to conditions  
2 in which people live, attend school, grow, and develop) and BP in South Asian children; and 2)  
3 to identify the most important aggregate correlates of BP in South Asian children.

## 4 **METHODS**

### 5 **Study Design**

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

### 13 **Recruitment**

14 Elementary school and high-school children (n= 762) were recruited using community-  
15 based methods in two Canadian cities (Brampton, Ontario and Surrey, British Columbia) by  
16 convenience sampling between 2012 and 2016. Letters were first sent to school boards to  
17 identify elementary schools with a high rate of South Asian enrolment. Once schools were  
18 identified, packages containing an invitation letter, a RICH-LEGACY study description and  
19 consent forms were sent to parents/guardians of children enrolled in the identified schools.  
20 Information stands were also placed at the participating elementary schools before and after  
21 school hours to reach out to parents with more information about the study. Additionally, the  
22 study was advertised through venues used by South Asian groups including newspapers, local

1 television stations, community centres, worship centres and festivals. Inclusion criteria included:  
2 children (in elementary or high school) having at least three grandparents of South Asian origin;  
3 and participants being able to provide consent (parents) and assent (children). Research assistants  
4 fluent in Hindi and Punjabi were responsible for participant recruitment and data collection. The  
5 research assistants who were involved in the measurements all undertook training together  
6 through simulator sessions and were retrained if variations in measurement protocol were  
7 observed by the research coordinator. This process was repeated for a few days to ensure  
8 accuracy and consistency amongst the research assistants in the assessment of the measurements  
9 collected in this study. In addition, written materials (including consent forms) were provided in  
10 English, Punjabi, Hindi and Urdu as needed.

### 11 **Participant Assessment**

12 Participants for the RICH-LEGACY study were assessed regarding socio-demographic  
13 variables including age, sex and parental education. In certain cases, parents or guardians helped  
14 complete certain sections of the child's questionnaire. Children's perception of body image was  
15 assessed using Stunkard's silhouettes, a rating scale from one to nine with increases related to  
16 increased silhouette size<sup>14</sup>, that assesses perception of size and body dissatisfaction. This figure  
17 rating scale has been shown to be a valid indicator of determining weight status in children<sup>15</sup>.  
18 Feeding practices were assessed using the childhood feeding questionnaire<sup>16</sup>. Exposure to  
19 bullying was assessed by asking participants if they had experienced bullying or violence at  
20 school. This variable was assessed because of its role as a known stressor in children and its  
21 possible impact on pathways known to be involved in BP regulation such as the hypothalamic-  
22 pituitary-adrenal (HPA) axis<sup>17</sup>. Additionally, level of acculturation was assessed using the  
23 Acculturation Rating Scale for Mexican Americans-II (ARSMA- II) adapted for use in South

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3 1 Asians by Stigler *et al*<sup>18</sup>. This scale assesses an individual's identification with their heritage  
4  
5 2 based on different domains including language preferences, media preferences, and preferences  
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7 3 regarding food and other consumer goods using 24 questions<sup>18</sup>. The adapted questionnaire is  
8  
9 4 grouped into two scales: the Western scale and the traditional scale. The traditional acculturation  
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11 5 score measures children's acceptance of traditional Indian cultural attributes while the  
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13 6 Westernized acculturation score measures the degree to which South Asian children identify with  
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15 7 Western culture.  
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20 8 Participants completed a semi-quantitative food frequency questionnaire (FFQ) that  
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22 9 assessed intake of fruits and vegetables and fast foods consumption. The FFQ was adapted from  
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24 10 the INTERHEART FFQ, which was validated in an international cohort that included South  
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26 11 Asians<sup>19</sup>. Physical activity was assessed using a standardized questionnaire that quantified sports  
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28 12 and other activities including leisure, household chores and sedentary factors (screen time and  
29  
30 13 homework) during school and outside of school over the past month. All activities were then  
31  
32 14 expressed as metabolic-equivalent-of-task (MET) minutes. Self-reported exposure to second-  
33  
34 15 hand smoke was assessed to characterize children's passive exposure to smoking and defined as  
35  
36 16 a minimum of five consecutive minutes during which inhalation of other people's smoke occurs.  
37  
38 17 Hand-grip strength, a measure of muscular strength, was measured on the non-dominant hand by  
39  
40 18 study personnel with a Jamar dynamometer utilizing standardized protocol<sup>20</sup>.  
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### 46 19 **Anthropometric Characteristics**

47  
48 20 Height was measured to the nearest 0.1 cm using a right angle triangle and a calibrated  
49  
50 21 wall mounted scale. Weight was measured to the nearest 0.1 kg with the subject in light clothing  
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52 22 using an electronic scale. Body mass index (BMI) was first calculated from weight in kilograms  
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1 divided by height in meters squared before being converted to z-scores using WHO growth  
2 references for young people aged 5-19 years<sup>21</sup>.

3           Waist circumference (WC) was recorded in centimetres as the average of two measures  
4 taken halfway between the lower rib margin and the iliac crest against the skin following a  
5 normal expiration. Waist circumference was assessed using non-stretching measuring tape by  
6 trained team members. Waist-to-height ratio (WtHR) was then calculated by dividing waist  
7 circumference by height. Both WC and WtHR were transformed to z scores using published  
8 lambda-mu-sigma (LMS) values for age and sex based on the third US National Health and  
9 Nutrition Examination Survey (NHANES III)<sup>22</sup>. Transforming the anthropometric measures to z-  
10 scores allowed for the standardized comparisons across populations of children of similar ages  
11 and sex.

## 12 **Blood Pressure and Heart Rate**

13           Blood pressure and heart rate were measured in the left arm using the Omron HEM-  
14 711DLX automated blood pressure monitor with appropriate sized cuffs following 10 minutes of  
15 seated rest. Three BP and heart rate measures were taken over a 10-minute period and the  
16 average of the three was recorded. Subsequently, BP was transformed to standard deviation  
17 scores and percentiles adjusted for age, sex and height according to the fourth National High  
18 Blood Pressure Education Program (NHBPEP) working group in children and adolescents<sup>23</sup>.  
19 Systolic and diastolic hypertension were defined using the NHBPEP recommendations as  
20 average systolic blood pressure or diastolic blood pressure equal to or greater than the 95<sup>th</sup>  
21 percentile for sex, age and height.

## 22 **Parental Variables**

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3 1 Parents of the children recruited for this study provided information on parental education  
4  
5 2 (father's and mother's education). In a smaller subset of the South Asian children (n=271),  
6  
7 3 parental history of hypertension (yes or no) was assessed in order to explore the potential impact  
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9 4 of heritable factors on children's BP z-scores and hypertension. Father's education was used as a  
10  
11 5 proxy variable for socioeconomic status in this study. Fathers' education levels were categorized  
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13 6 as: those with no formal education; those with primary/secondary school education; those with a  
14  
15 7 trade school degree/diploma; and those with a college or university degree. Parent's smoking  
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17 8 status was self-reported and categorized as non-smoker, former smoker, or current smoker.  
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## 22 9 **Statistical Analysis**

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25 10 All continuous variables were examined using P-P plots and found to be normally  
26  
27 11 distributed. For descriptive analysis, continuous variables were presented as means and standard  
28  
29 12 deviations while categorical variables were reported as counts and percentages. Independent t-  
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31 13 test analysis was used to assess sex differences in continuous variables, while chi-square tests  
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33 14 were used to assess sex differences in categorical variables.  
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38 15 To explore the associations among the range of physiological, lifestyle and social  
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40 16 variables with systolic and diastolic BP, unadjusted linear regression was used. These models  
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42 17 were then adjusted for potential confounding effect of child age, sex and father's education.  
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44 18 These confounders were selected based on their well –documented independent associations with  
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46 19 the outcome variable in research studies<sup>11,13</sup>. Although, the conversion of to z-scores provides  
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48 20 age and sex adjusted data, we chose to still include age and sex as confounders to adjust for  
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50 21 potential residual effects unaccounted for by the reference charts used in this study. Similarly,  
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52 22 unadjusted and adjusted (age, sex and father's education) logistic regression analysis was used to  
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1 explore clinically-relevant associations among the multifactorial variables with systolic and  
2 diastolic hypertension. While age and sex were identified as potential confounders in the  
3 association between the other variables assessed in this study with BP and hypertension, we also  
4 wanted to examine their independent associations with BP and hypertension. To do this, they  
5 were each removed from the list of confounders we adjusted for when exploring their effect on  
6 BP z-scores and hypertension (i.e., sex was adjusted for age and father's education, while age  
7 was adjusted for sex and father's education.)

8 To address the second study objective, stepwise multiple linear regression analyses were  
9 used to identify the combination of risk factors that best explained the variance in BP in South  
10 Asian children. The stepwise regression method enables the identification of the aggregate  
11 combination of correlates that has the highest contributory effect to the outcome variable.  
12 Specifically, for this analysis, we utilized the backward method to select the list of multifactorial  
13 correlates that provide significant contribution to the outcome (systolic and diastolic BP z-  
14 scores) using an entry criterion of  $p < 0.05$  and a removal criterion of  $p > 0.10$ . The specific list of  
15 correlates (age, sex, height, weight, heart rate, BMI z-score, WC z-score, WHtR z-score, parental  
16 history of hypertension, parental education, exposure to bullying and violence, traditional and  
17 western acculturation scores, physical activity in school and outside school, dietary variables and  
18 second-hand smoking) considered for introduction in the backward stepwise regression model  
19 were chosen *a priori* based on literature evidence<sup>13</sup> and whether they had a p value  $< 0.05$  in  
20 unadjusted analysis. Using the aforementioned criteria, the following variables were considered  
21 in step-wise regression analysis: age, sex, height, weight, BMI z-score, WC z-score, WHtR z-  
22 score, heart rate, western acculturation score, child's perception of body image, and grip  
23 strength. In addition to these variables, father's education, daily intake of fast foods and total

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3 1 daily intake were considered in diastolic BP z-score models. The adjusted R squared value for  
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5 2 each model provides the combined contribution of the variables in the model to the variance in  
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7 3 BP z-scores. The full list of variables initially identified from literature search were also  
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9 4 considered in logistic regression models with hypertension. Statistical analysis was done using  
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11 5 SPSS version 24.0. P values <0.05 were considered statistically significant. This study was  
12  
13 6 written in line with the Strengthening the Reporting of Observational studies in Epidemiology  
14  
15 7 (STROBE) guidelines<sup>24</sup>

## 8 **Patient and Public Involvement**

9 The research questions and outcome measures in this study were chosen by this team of  
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11 researchers and clinicians with extensive experience working with the South Asian population to  
12  
13 better understand the potential health risks faced by South Asian children. No patients were  
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15 involved in setting the research question in development of the research question or study design.  
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17 There are currently no plans to disseminate the results of this research study to study participants  
18  
19 or to the relevant patient population.

## 15 **RESULTS**

16 This study included 360 boys (47%) and 402 girls ranging from 5.8 to 17.0 years (mean  
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18 age  $9.5 \pm 3.0$  years), with no statistically significant difference observed for age by sex (table 1).  
19  
20 The prevalence of systolic hypertension in this population was 12%. South Asian boys were  
21  
22 more physically active outside school than girls ( $p=0.04$ ); higher WC z-score ( $p<0.001$ ); higher  
23  
24 WHtR z-score ( $p=0.02$ ); lower heart rate ( $p=0.047$ ); higher systolic BP z-scores ( $p=0.001$ );  
25  
26 higher prevalence of systolic hypertension ( $p=0.01$ ); had lower traditional acculturation score  
27  
28 ( $p=0.02$ ); and significantly higher exposure to bullying and violence at school ( $p=0.025$ ).

## 1 Correlates of Systolic BP and Systolic Hypertension

2 In unadjusted linear regression analysis with systolic BP z-scores, weight (kg) ( $\beta = 0.005$ ,  
3 95% CI= 0.001, 0.01,  $p=0.022$ ), BMI z-score ( $\beta = 0.289$ , 95% CI= 0.246, 0.333,  $p<0.001$ ), WC z-  
4 score ( $\beta = 0.266$ , 95% CI= 0.213, 0.319,  $p<0.001$ ), WHtR z-score ( $\beta = 0.271$ , 95% CI= 0.219,  
5 0.324,  $p<0.001$ ), heart rate (beats per minute) ( $\beta = 0.019$ , 95% CI= 0.015, 0.023,  $p<0.001$ ), and  
6 the child's perception of their body image (using Stunkard's silhouettes) ( $\beta = 0.136$ , 95% CI=  
7 0.083, 0.189,  $p<0.001$ ) were found to be positively associated with systolic BP z-score. In  
8 contrast, we found that compared to male sex, female sex had lower systolic BP z-score ( $\beta = -$   
9 0.246, 95% CI= -0.385, -0.108,  $p<0.001$ ). Similarly, age (years) ( $\beta = -0.060$ , 95% CI= -0.084, -  
10 0.037,  $p<0.001$ ), children's western acculturation score ( $\beta = -0.021$ , 95% CI= -0.036, -0.006,  
11  $p=0.007$ ) and height (cm) ( $\beta = -0.006$ , 95% CI= -0.010, -0.002,  $p=0.007$ ) were negatively  
12 associated with systolic BP z-score. After adjustment for confounders, the association between  
13 western acculturation attenuated and became non-significant, while the association observed  
14 between height and systolic BP z-score became positive. Associations between children's grip  
15 strength and daily physical activity in school with systolic BP z-score also became significant  
16 upon adjustment (table 2).

17 In stepwise regression analysis, the combination of age, sex, BMI z-score, heart rate and  
18 weight were observed to be the most important correlates of systolic BP z-score, accounting for  
19 30% of the systolic BP z-score variance of South Asian children (Table 3).

20 In unadjusted logistic regression analysis, female sex was associated with lower odds of  
21 developing systolic hypertension (odds ratio (OR) = 0.56, 95% CI= 0.36, 0.87,  $p=0.011$ ).

22 Associations were also observed with weight (kg) and systolic hypertension (OR= 1.02, 95%

1 CI= 1.01, 1.04,  $p<0.001$ ), BMI z-score and systolic hypertension (OR= 2.22, 95% CI= 1.84,  
2 2.68,  $p<0.001$ ), WC z-score and systolic hypertension (OR= 2.65, 95% CI= 2.06, 3.43,  $p<0.001$ )  
3 and WHtR z-score and systolic hypertension (OR= 2.47, 95% CI= 1.95, 3.13,  $p<0.001$ ).  
4 Similarly, associations were observed between heart rate (beats per minute) and systolic  
5 hypertension (OR=1.04, 95% CI= 1.02, 1.06,  $p<0.001$ ), child's perception of body image and  
6 systolic hypertension (OR= 1.50, 95% CI= 1.25, 1.79,  $p<0.001$ ) and western acculturation score  
7 with systolic hypertension (OR= 0.95, 95% CI=0.90, 1.00,  $p=0.03$ ). Upon adjustment for  
8 confounders, the associations between western acculturation score and systolic hypertension  
9 attenuated and became non-significant. The association between grip strength and systolic  
10 hypertension became significant upon adjustment (Figure 1).

### 11 **Correlates of Diastolic BP and Diastolic Hypertension**

12 In unadjusted linear regression analysis of multifactorial variables with diastolic BP z-  
13 score, negative associations with diastolic BP z-score were observed between age (years) ( $\beta= -$   
14 0.061,  $p<0.001$ ), height (cm) ( $\beta= -0.009$ ,  $p<0.001$ ), western acculturation score ( $\beta= -0.018$ ,  
15  $p=0.007$ ), fathers' level of education ( $\beta= -0.054$ ,  $p=0.047$ ), total daily food intake ( $\beta= -0.016$ ,  
16  $p=0.005$ ), fast foods ( $\beta= -0.065$ ,  $p=0.048$ ) and grip strength (kg) ( $\beta= -0.019$ ,  $p<0.001$ ).  
17 Conversely, significant positive associations with diastolic BP z-score were observed between  
18 heart rate ( $\beta= 0.018$ ,  $p<0.001$ ), BMI z-score ( $\beta= 0.156$ ,  $p<0.001$ ), WC z-score ( $\beta= 0.120$ ,  
19  $p<0.001$ ), WHtR z-score ( $\beta= 0.128$ ,  $p<0.001$ ), and children's perception of their body image  
20 (using Stunkard's silhouettes) ( $\beta= 0.053$ ,  $p=0.007$ ). After adjustment for confounders the  
21 association between height, western acculturation score, father's level of education, total daily  
22 food intake, fast food consumption and grip strength attenuated and became non-significant  
23 (Table 2).

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2  
3 1 In stepwise regression analysis, the combination of age, BMI z-score, heart rate and daily  
4  
5 2 intake of fast foods were observed to be the most important aggregate correlates of diastolic BP  
6  
7 3 z-score, accounting for 23% of the diastolic BP z-score variance of South Asian children (Table  
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9 4 3).

10  
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13 5 In unadjusted logistic regression analysis, associations were observed between age  
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15 6 (years) (OR= 0.71, 95% CI= 0.55, 0.92, p=0.01), height (OR= 0.97, 95% CI= 0.94, 1.00,  
16  
17 7 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%  
18  
19 8 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  
20  
21 9 (beats per minute) (OR=1.06, 95% CI= 1.03, 1.10, p<0.001) and grip strength (kg) (OR= 0.92,  
22  
23 10 95% CI= 0.86, 0.99, p=0.024) with diastolic hypertension. Upon adjustment for confounders, the  
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25 11 association between height, grip strength and diastolic hypertension attenuated and became non-  
26  
27 12 significant (Figure 2).

## 13 **DISCUSSION**

14  
15 14 This study provides information on a range of correlates of systolic and diastolic BP z-  
16  
17 15 scores in a population of South Asian children. While results from unadjusted models highlight  
18  
19 16 the presence of a multifactorial relationship for BP and hypertension, the disappearance of most  
20  
21 17 of the social and lifestyle risk factors upon adjustment highlights the contribution of variables  
22  
23 18 such as age, sex, adiposity, height, heart rate, and grip strength to the risk of elevated BP and  
24  
25 19 hypertension in South Asian children.

26  
27 20 It is well documented that the burden of hypertension has precipitously increased in the  
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29 21 pediatric population<sup>25</sup>. In addition, some studies have documented higher prevalence of  
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31 22 hypertension in certain ethnic groups such as South Asians<sup>11</sup>. Although our sample was based on

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3 1 convenience and non-representative given that sampling was restricted to two Canadian cities,  
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5 2 the prevalence of hypertension in our study at 12% is consistent with age, sex and height  
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7 3 adjusted estimates from Jafar *et al*<sup>11</sup> using a nationally-representative survey of Pakistani  
8  
9 4 children age 5 to 14 years, but higher than 5.2% prevalence from one cross-sectional study of  
10  
11 5 Indian children ages 5 to 12 years<sup>26</sup>. Our estimates also appear higher than estimates from  
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13 6 Canadian children ages 6 to 19 years where 4% of children were said to have hypertension and  
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15 7 prehypertension<sup>27</sup>. When stratified by sex, we found significantly higher rates were observed for  
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17 8 boys at 15% compared to girls at 9%. This is consistent with results from studies in other  
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19 9 children which have reported higher hypertension prevalence in boys<sup>28,29</sup>, and results from  
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21 10 regression analysis which found female sex to be associated with lower odds of hypertension.  
22  
23 11 This risk differential has been attributed to the presence of an anti-inflammatory immune profile  
24  
25 12 in females and pro-inflammatory profile in males<sup>30</sup> — underscoring the potential for intervention  
26  
27 13 efforts aimed at addressing sex-based disparities.

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34 14 Consistent with research conducted in South Asian children<sup>11,31</sup> and research conducted  
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36 15 in other childhood populations of different ethnicities<sup>28,32–36</sup>, we observed positive associations  
37  
38 16 between measures of adiposity and BP and hypertension after adjusting for covariates. The  
39  
40 17 consistency of the association observed across the range of adiposity metrics assessed  
41  
42 18 underscores the significant contribution of increasing adiposity to the prevalence of hypertension  
43  
44 19 in South Asian children. Moreover, the positive association between grip strength (a measure of  
45  
46 20 muscle strength) with systolic BP z-score and hypertension upon adjustment in this study raises  
47  
48 21 questions about the benefits of strength training in children. The benefits of physical activity  
49  
50 22 including aerobic exercise in relation to hypertension remain clear; however, the benefits of  
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52 23 strength training in relation to hypertension risk, relative to the benefits of aerobic exercise,  
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3 1 appear questionable<sup>37</sup>. It is unclear what might be responsible for the positive effect observed  
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5 2 between grip strength and systolic BP z-score; however, findings from our study appear  
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7 3 consistent with studies which have explored this association in Chinese<sup>38</sup> and American  
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9 4 children<sup>39</sup>.

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13 5 The consistent association between adiposity and hypertension, including the higher  
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15 6 prevalence of hypertension in this population, reinforces their connections through a range of  
16  
17 7 complex mechanistic pathways. Some of these pathways involve the activation of the renin-  
18  
19 8 angiotensin-aldosterone system (RAAS) or sympathetic nervous system. Specifically, the South  
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21 9 Asian phenotype of higher body fat<sup>7</sup>—especially the visceral type which has been identified in  
22  
23 10 adults<sup>6</sup>—when compared to their Caucasian peers, could activate the formation of pro-  
24  
25 11 inflammatory cytokines such as Interleukin 6 (IL-6) which results in physiological changes that  
26  
27 12 could lead to endothelial and vascular dysfunction through the development of insulin  
28  
29 13 resistance<sup>40</sup>, resulting in an increased predisposition for hypertension. The positive association  
30  
31 14 between height and BP in this population could be explained by cerebral perfusion requirements  
32  
33 15 where higher BP is needed in taller people to achieve optimal cerebral perfusion owing to  
34  
35 16 hydrostatic pressure differences in taller and shorter individuals<sup>41</sup>. However, more research in  
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37 17 South Asian children is warranted to corroborate our findings given the difference observed in  
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39 18 direction of association in unadjusted and adjusted models.  
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46 19 The positive association we found between the child's perception of body image and BP  
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48 20 may be due to this variable mirroring children's weight status or conversely, a marker for a  
49  
50 21 graded increase in stress levels, owing to societal criticism of fatter body types, which could  
51  
52 22 have insidious effects for hypertension risk through its impact on the neuro-endocrine system<sup>42</sup>.  
53  
54 23 Additionally, a range of social and lifestyle variables were also found to be associated with BP z-  
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1 score in unadjusted analysis but became non-significant upon adjustment for confounders. While  
2 results from unadjusted associations may demonstrate links between risk factor and outcome, the  
3 disappearance of the association upon adjustment for socio-demographic variables highlights the  
4 links between these variables and suggests that the pathway linking these factors with BP might  
5 be interdependent.

6 The stepwise regression model shows that correlates from this study explained only about  
7 30% of the variance of systolic BP z-score and 23% of the variability of diastolic BP z-scores. It  
8 is possible that some of this unexplained variance might be explained by genetics, as it has been  
9 suggested that about 30% to 60% of the variance in BP may be heritable<sup>43,44</sup>. Yet the lack of  
10 association between parental hypertension and child BP in the subset of parents of participants  
11 who provided this data would appear to contradict these findings for this population of South  
12 Asian children. However, it is likely that the subset of parents of child participants who provided  
13 this information might not be completely representative of the entire cohort, thereby biasing the  
14 results. Still, even accounting for potential genetic contributions, a significant amount of the BP  
15 variance remains unexplained. More research is needed to provide insight regarding the  
16 contributory effects of other potential variables that might contribute to risk of elevated BP in  
17 South Asian children.

18 Notably, null associations were also observed for certain variables in this study that have  
19 been found to be significantly associated with BP and hypertension in other child populations.  
20 For example, parental history of hypertension, dietary factors (such as consumption of fruit and  
21 vegetables) and exposure to second hand smoking have been linked in other studies to child BP  
22 but had no significant impact in this study. This could be reflective of the potential biases  
23 associated with using self-reports or may highlight how interactions between genes and

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3 1 environment/lifestyle shape risk factor susceptibilities — underscoring the need for more ethnic-  
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5 2 based and ethnic comparison studies when exploring risk associations.  
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### 8 9 3 **Study Limitations**

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11 4 This study has limitations. First, although we sought to recruit a representative sample of  
12  
13 5 urban South Asian children, it was not a random sample. However, there is likely to be minimal  
14  
15 6 effect on the relationships between the ranges of risk factors evaluated in this study. Second, this  
16  
17 7 is a cross-sectional study and is therefore unable to provide insights into causal associations  
18  
19 8 between the risk factor variables and long term CVD risk in South Asian children. Third,  
20  
21 9 potential recall biases may have occurred as a result of using self-report data for some of the  
22  
23 10 variables including diet and physical activity measures. Fourth, the use of father's education as a  
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25 11 measure of socioeconomic status pose limitations. Variables like household income would have  
26  
27 12 been preferred, however only a subset of participants provided data on household income, thus  
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29 13 its use would have excluded a significant portion of children in this study. However, as a means  
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31 14 to confirm the results, we separately adjusted for mother's education and no deviation in study  
32  
33 15 results was observed. Last, the lack of data collection on sexual maturity status could potential  
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35 16 confound the study results obtained here. However, the adjustment for age in this study, which  
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37 17 acts as a proxy variable for sexual maturity might help mitigate the bias. These limitations are in  
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39 18 part addressed by strengths of this study which lies in its large sample size of South Asian  
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41 19 children and in the wide range of risk factors examined.  
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### 49 20 **Implications**

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52 21 Our findings underscore a range of factors that may contribute to risk of elevated BP and  
53  
54 22 hypertension in South Asian children. Consequently, public health interventions such as those  
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1 that emphasize prevention such as population-based health education and lifestyle modification  
2 that considers unique cultural contexts may provide significant potential in addressing the burden  
3 of hypertension in this population. There are also implications for clinical settings. Specifically,  
4 our findings suggest that while South Asian children may benefit from interventions aimed at  
5 reducing obesity to address the comparatively higher burden of hypertension in this population,  
6 there are certain sub-groups who could benefit from more targeted preventive interventions in  
7 primary care settings — such as males, children with increased adiposity, taller children, and  
8 children with increased heart rate, or children with a combination of these factors.

## 9 CONCLUSION

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

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19 Rangarajan conceptualized the study, contributed to study design and reviewed the manuscript.  
20 Adeleke Fowokan conceptualized the study, drafted the initial manuscript, carried out statistical  
21 analysis and revised the manuscript. Dr. Waddell and Dr. Rosin contributed to the design of the  
22 study, reviewed and revised the manuscript.

23 All authors approved the final manuscript as submitted and agree to be accountable for all  
24 aspects of the work.

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8  
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10  
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12 7 Care REB, and the Hamilton Integrated REB

13  
14 8 **Data sharing statement:** Raw data are held by the lead author of the study in accordance with  
15 9 ethics guidelines.

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1 Table 1: Physiological, lifestyle and sociodemographic characteristics of South Asian children  
 2 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 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 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 (METmins/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

1 \*Exposure defined as a minimum of five consecutive minutes during which inhalation of other  
 2 people's smoke occurs  
 3 BP=Blood pressure, BMI=body mass index, WC= waist circumference, WHtR= waist to height  
 4 ratio, SBP= systolic blood pressure, DBP= diastolic blood pressure  
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1 Table 2: Adjusted linear regression between multifactorial risk factors with systolic and diastolic  
 2 BP z scores

	Systolic BP z score	Diastolic BP z score
Age <sup>a</sup>	-0.054 (-0.078, -0.029), p<0.001	-0.057 (-0.075, -0.039), p<0.001
Female sex (vs Male) <sup>b</sup>	-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 image	0.183 (0.128, 0.239), p<0.001	0.104 (0.064, 0.144), p<0.001
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	-0.127 (-0.484, 0.230), p=0.484	-0.063 (-0.336, 0.209), p=0.648

hypertension		
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

1 *Model adjusted for age, sex and father's education*

2 *Values presented are  $\beta$  (95% confidence intervals), and p values*

3 *BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure, MET=Metabolic equivalent of task*

4 *<sup>a</sup>Age was adjusted for sex and father's education*

5 *<sup>b</sup>Sex was for adjusted for age and father's education*

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1 Table 3: Stepwise linear regression analysis showing the aggregate correlates of BP z-score in  
 2 South Asian children

Stepwise multiple linear regression models					
	Variable	B	95%	P value	Adjusted R <sup>2</sup>
Systolic BP z-score	Child's age	-0.132	-0.202, -0.062	<0.001	0.294
	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	
Diastolic BP z-score	Child's age	-0.027	-0.048, -0.007	0.01	0.228
	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	

3 *BMI=body mass index, BP= blood pressure*

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3 1 Figure 1: Adjusted odds ratio for the association between the multifactorial variables with  
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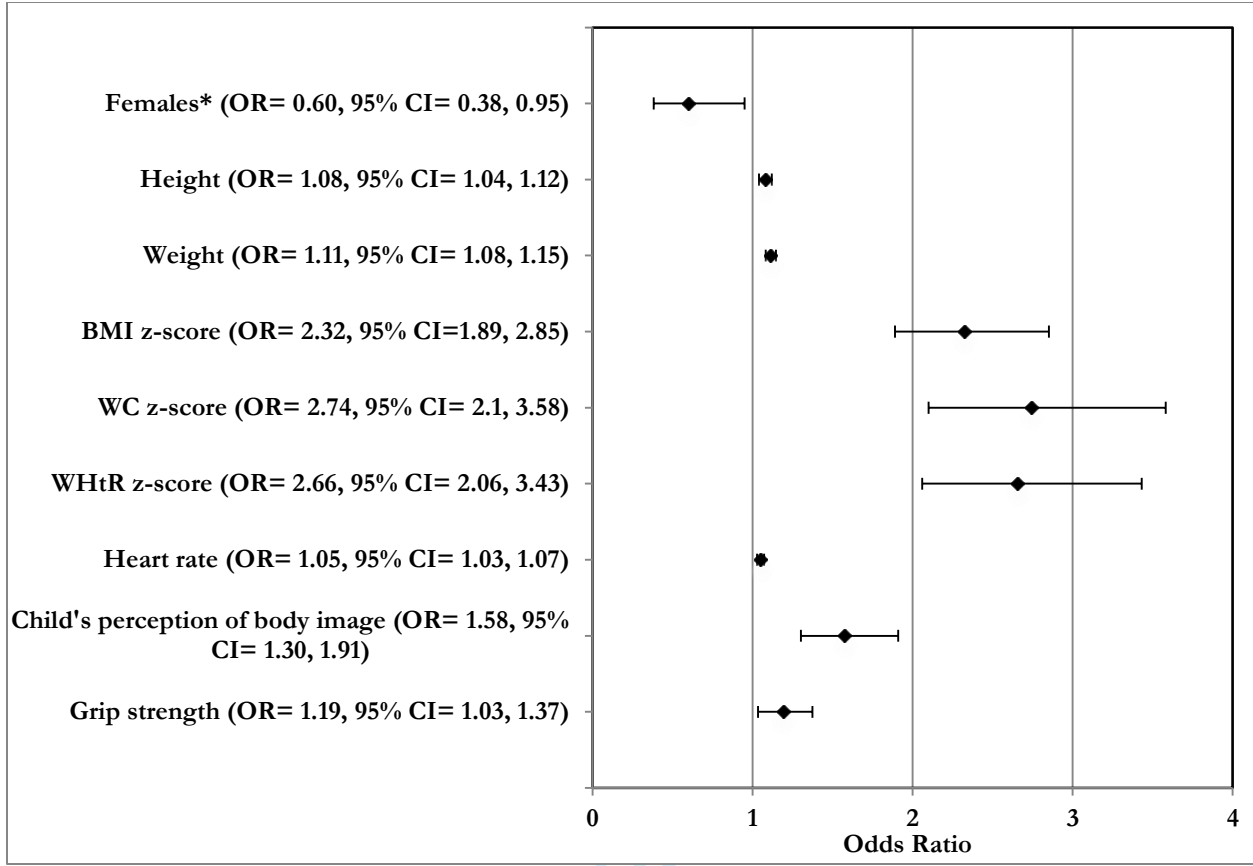
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1 Figure 2: Adjusted odds ratio for the association between the multifactorial variables with  
2 diastolic hypertension

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Model adjusted for age, sex and father's education

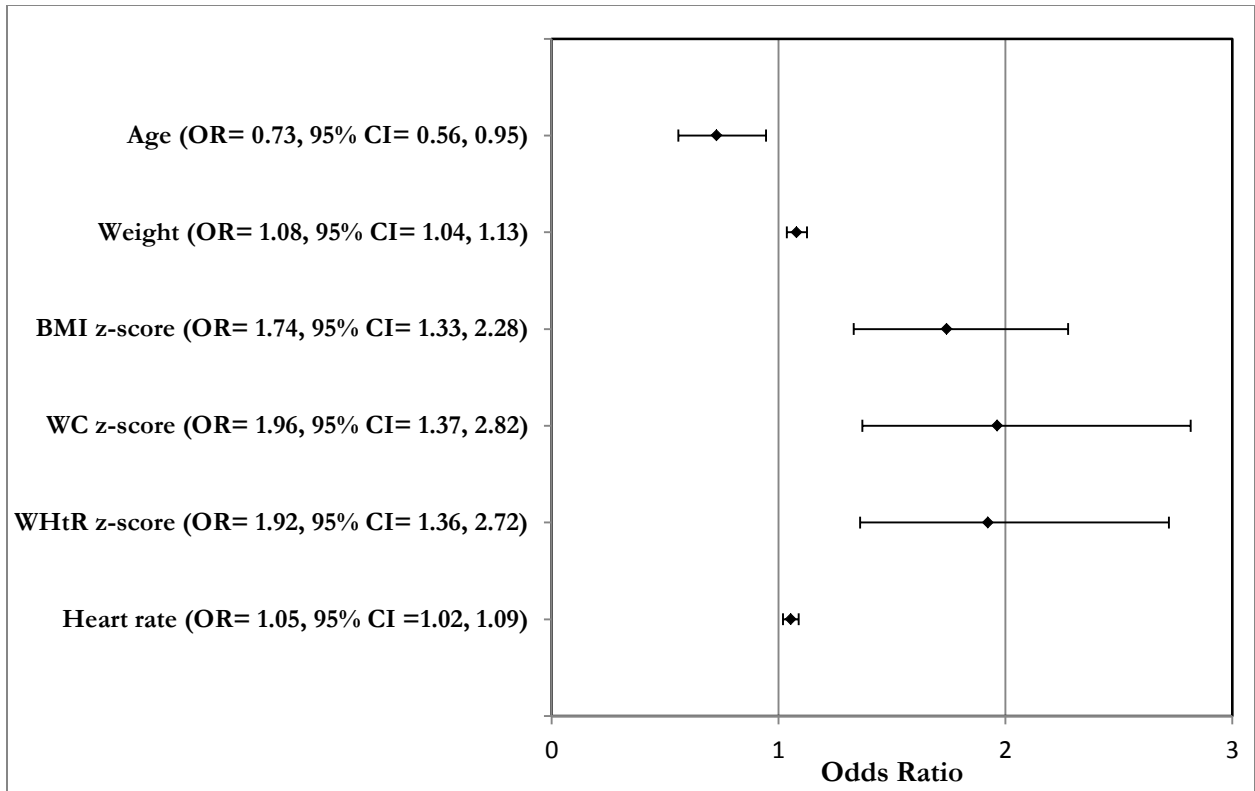
Values presented are odds ratio (95% confidence intervals)

BMI= body mass index, WC= waist circumference, WHtR= waist to height ratio, BP =blood pressure

\*compared to males

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*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*

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	N/A
	(c) Explain how missing data were addressed	7	
	(d) If applicable, describe analytical methods taking account of sampling strategy	N/A	
	(e) Describe any sensitivity analyses	N/A	
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	24
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11

		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).