Paediatrics & Child Health, 2021, e158–e165
doi: 10.1093/pch/pxaa026
Original Article
Advance Access publication 30 March 2020

OXFORD

Original Article

Prevalence of high blood pressure among Canadian Children: 2017 American Academy of Pediatrics guidelines with the Canadian Health Measures Survey

Suzanne K. Robinson MD MSc[1], Celia J. Rodd MD MSc FRCPC[2], Daniel L. Metzger MD FRCPC[3], Atul K. Sharma MD MSc FRCPC[1]

[1]Department of Pediatrics and Child Health, University of Manitoba, Winnipeg, Manitoba; [2]Department of Pediatrics and Child Health, Section of Pediatric Endocrinology, University of Manitoba, Winnipeg, Manitoba; [3]Department of Pediatrics, Section of Pediatric Endocrinology, University of British Columbia, Vancouver, British Columbia

Correspondence: Celia J. Rodd, Department of Pediatrics and Child Health, University of Manitoba, 685 William Ave, FE307, Winnipeg, Manitoba, R3E 0Z2. Telephone 204-787-1741, fax 204-787-1655, e-mail crodd@hsc.mb.ca

Research undertaken at the University of Manitoba.

REB Approval: University of Manitoba's Research Ethics Board.

Abstract

Background: We assess the impact of the 2017 American Academy of Pediatrics (AAP) guidelines on the prevalence of high blood pressure (BP) in generally healthy Canadian children and identify risk factors associated with high BP (elevated, stage 1, or stage 2 at a single visit).
Methods: A cohort of 7,387 children aged 6 to 18 years in the Canadian Health Measures Survey (CHMS, 2007 to 2015) had BPTru oscillometry with centiles and stages assigned using both the 2017 AAP guidelines and the 2004 Fourth Report from the National Institute of Health/National Heart Lung and Blood Institute (NIH/NHLBI).
Results: Although both shifted upwards significantly, mean population systolic BP and diastolic BP percentiles are now 24.2 (95% confidence interval: 23.3 to 25.2) and 46.4 (45.3 to 47.6). As a result, the population prevalence of high BP increased from 4.5% (3.9 to 5.2, NIH/NHLBI) to 5.8% (5.0 to 6.6, AAP), less than in US children measured by auscultation (14.2%, 13.4 to 15.0). Children with high BP were more likely to be overweight/obese, to be exposed to prenatal/household smoking, and to have hypertriglyceridemia, without differences in dietary salt, infant breastfeeding, neonatal hospitalizations, or exercise frequency.
Conclusion: The 2017 AAP guidelines increase the prevalence of high BP in Canadian children; Canadian prevalence appears lower than in the USA. This may reflect differences in measurement methods or in the prevalence of childhood overweight/obesity between countries, that is, 31.1% (28.9 to 33.3) versus 40.6% (39.5 to 42.0), respectively. Those with high BP were more likely to have other cardiac risk factors, including overweight/obesity, prenatal/household smoking exposure, and hypertriglyceridemia.

Keywords: *Clinical practice guidelines; Epidemiology; High blood pressure; Hypertension; Multistage sample design*

Received: October 5, 2019; Accepted: January 31, 2020

The 2017 American College of Cardiology (ACC) provided new recommendations for the definition and treatment of hypertension in adults, targeting blood pressure (BP) <130/80 (1,2). New clinical practice guidelines for children were also published by the American Academy of Pediatrics (AAP) (3) to replace those in the Fourth Report from the National Institute of Health's National Heart, Lung, and Blood Institute (NIH/NHLBI) (4). Although based on the same core data set (5), children with overweight or obesity (OW/OB) were excluded from reference data; new cut-offs were developed to define elevated BP, stage 1 hypertension, and stage 2 hypertension; and definitions were aligned with new 2017 ACC adult guidelines (1,3).

We have previously examined the NHANES 1999 to 2016 cohort to assess the impact of the new guidelines in generally healthy US children (6), reporting an increase in population prevalence of high BP (elevated, stage 1, or stage 2 at a single visit) from 11.8% to 14.2%. Care must generally be taken before extrapolating US results to Canadian children (7) with different rates of childhood OW/OB (6,8,9).

Our primary objective was to assess the impact of the 2017 AAP guidelines on the prevalence of high BP in generally healthy Canadian children. Secondarily, we wished to characterize those with high BP compared to normotensive controls and compare cardiac risk profiles.

METHODS

Data source

The CHMS is a comprehensive national survey involving health questionnaires, physical measurements, and laboratory samples for Canadians aged 3 to 79 years and represents 96% of the Canadian population (10–12). Participants ≥14 years or parents provided written consent. CHMS Cycles 1 to 4 (2007 to 2015) provide data for 7387 generally healthy children ages 6 to 18 years after excluding (N=29) those with kidney disease; systemic glucocorticoid use; or missing birth date, height, weight, or BP.

Age, sex, height, weight, and BP were collected in mobile exam centres. Weights were measured on Mettler Toledo VLC scales (Mississauga, ON, Canada). Heights were measured using a ProScale M150 Digital Stadiometer (Fletcher, NC). Waist circumferences were reported using the NIH protocol (11).

Blood pressures

BP was measured using BPTru Medical Devices (Coquitlam, BC, Canada) on the right arm with six measurements one minute apart (13,14). Mean values for both systolic (SBP) and diastolic BP (DBP) were calculated after dropping the first reading (15). SBP and DBP percentiles were calculated using both NIH/NHLBI (2004) and the AAP (2017) guidelines (Table 1) (3,4). For both, 'high BP' was defined as mean single-visit BP values consistent with elevated BP (previously labeled 'prehypertension'), stage 1 hypertension, or stage 2 hypertension (2,6). If BP stage worsened with the 2017 guidelines, subjects were considered to have been reclassified upwards.

Exposure variables

Age- and sex-specific z-scores (z) were based on World Health Organization (WHO) (16,17) references for height, weight, and body mass index (BMI). Standard WHO definitions for children aged 5 to 19 years were used for overweight (BMIz 1 to 2) and obesity (BMIz >2). Waist circumference and waist/height ratio z-scores were based on the NHANES reference data (18).

Additional data included education level (high school and below versus above high school), ethnicity (white versus other), country of birth (Canada versus other), and household income (<$30,000 versus ≥$30,000, the approximate low-income cut-off for a family of three during this period) (19). Geographic regions were assigned from east to west as Atlantic Canada, Quebec, Ontario, the Prairies, or British Columbia. General health inquiries included chronic health issues (yes versus no for asthma, diabetes, attention deficit disorder, learning disability, cancer), family history of high BP, a regular family doctor, and whether participants perceived themselves as 'sick' (true, somewhat true, or not true). Lifestyle variables included sleep trouble, weekly exercise frequency for ages 6 to 11 years, addition of salt to food, and smoking in the home. Birth history included birthweight, maternal age, single versus multiple birth, breastfeeding exposure, neonatal intensive care unit admission, and prenatal maternal smoking.

For laboratory measures, abnormal cut-points were defined by the NIH/NHLBI Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents and the American Diabetes Association (20,21). Système Internationale criteria were total cholesterol level ≥5.18 millimoles per litre (mmol/L), low-density lipoprotein cholesterol (Friedman method) ≥3.37 mmol/L, high-density lipoprotein cholesterol <1.41 mmol/L, and triglycerides ≥1.13 mmol/L for children aged ≤9 years or ≥1.47 mmol/L for those >9 years. For both children and adults, the American Diabetes Association defines a hemoglobin (Hb) A1c level of >5.6% or >38 millimoles/mole (mmol/mol) as abnormal, with 5.7 to 6.4% (39–47 mmol/mol) as prediabetes, and >6.5% (47.5 mmol/mol) as overt diabetes mellitus (21,22).

Statistical analysis

Descriptive statistics were carried out with STATA 15 (College Station, TX) and the svy package used to apply inverse probability survey sample and bootstrap weights; the former was

Table 1. Classification of blood pressure by 2004 NIH/NHLBI and 2017 AAP guidelines

NIH/NHLBI 2004		AAP 2017 for children 1–13 years		AAP 2017 for children ≥13years	
	SBP/DBP percentile		SBP/DBP percentile		Absolute Threshold
Normal	<90th	Normal	< 90th percentile	Normal	<120/<80 mmHg
Prehypertension	90th to <95th, or if BP exceeds 120/80 mmHg, even if below 90th centile, up to <95th percentile	Elevated BP	≥90th to <95th percentile or 120/80 mmHg to <95th percentile (whichever is lower)	Elevated BP	120/<80 to 129/<80 mmHg
Stage 1 hypertension	95th percentile to 99th percentile + 5 mmHg	Stage 1 hypertension	≥95th to <95th percentile + 12 mmHg, or 130/80 to 139/89 mmHg (whichever is lower)	Stage 1 hypertension	130/80 to 139/89 mmHg
Stage 2 hypertension	>99th percentile + 5 mmHg	Stage 2 hypertension	≥95th percentile + 12 mmHg or ≥140/90 mmHg (whichever is lower)	Stage 2 hypertension	≥140/90 mmHg

Adapted from Table 2 in references (3) and (4).

AAP American Academy of Pediatrics; BP Blood pressure; DBP Diastolic BP; mmHg Millimeters of mercury; NIH/NHLBI National Institute of Health's National Heart Lung and Blood Institute; SBP Systolic BP.

used to estimate weighted population means and prevalence while the latter provided standard errors, confidence intervals (CI), and P-values appropriate for the complex multistage sampling design (23,24). Z-scores were calculated with publicly available calculators (17,18,25). Continuous variables are reported as means with 95% CI, and categorical variables are reported as counts or proportions (95% CI). At the population level, continuous variables were compared by paired or unpaired t-tests, and proportions compared by chi-squared tests. P<0.05 was considered statistically significant for an a priori analysis plan.

In comparing 2004 and 2017 BP percentiles, population-weighted Bland–Altman plots were used to assess systematic bias (mean error) and 95% limits of agreement (LOA), that is, the range of discrepancies expected in day-to-day use (26,27).

Sample size

Assuming alpha=0.05, power=0.9, and a two-sided test of significance, the minimum detectable effect size is 1.2% for the change in prevalence with the new guidelines.

Ethics approval

This study was approved by the University of Manitoba's Research Ethics Board (reference number 0346 0513 000033). All analyses were performed in a secure Statistics Canada Research Data Centre.

RESULTS

Table 1 compares the 2004 and 2017 definitions of elevated BP, stage 1 hypertension, and stage 2 hypertension. In Table 2, the final study sample was 7,387 children and youth between the ages of 6.0–18.0 years, with an even sex distribution. Population z-scores for height, weight, BMI, and waist circumference were positive (i.e., higher than the reference population with mean=0). Rates of obesity (13.0%) and OW/OB (31.1%) were consistent with earlier reports (8,9).

Based on the 2017 guidelines, 93.4% of the sample (N=6,872) had normal BP versus 6.6% (N=484) with high BP. With the move to the 2017 AAP guidelines, the proportion of the population with high BP increased from 4.5% (95% CI:3.9 to 5.2) to 5.8% (5.0 to 6.6, P<0.001). Moreover, 261 children, representing 3.3% of the population, saw their BP stage reclassified upwards, with 114 (44%) new cases of high BP and 147 (56%) with a worsening clinical stage; due to minimum cell-size requirements, we are unable to report a more detailed breakdown. With the 2017 charts, mean SBP percentile was 24.2 (23.3 to 25.2) and mean DBP percentile was 46.4 (45.3 to 47.6). For 2004 charts, the corresponding percentiles were 21.3 (20.4 to 22.1) and 45.9 (44.8 to 47.1), respectively. Bland–Altman plots (Supplementary Figure 1) demonstrated an upward shift in SBP percentiles, with a mean discrepancy (bias) of +3.0 and 95% LOA of −2.0 to +12.0. The shift in DBP percentile was less dramatic with bias of +0.5 and LOA of −6.0 to +6.0. Both differences were statistically significant (paired t, P<0.001).

Table 2. Demographics for the sample and populations of included children aged 6–17 years from cycles 1–4 of the Canadian Health Measures Survey

Characteristics	Total sample (N=7,387)	Population
Biological determinants		
Sex (%)		
Male	50.8	51.8 (51.1–52.6)
Female	49.2	48.2 (47.3–48.9)
Age (years)	11.7	12.2 (12.2–12.3)
Age groups (%)		
6–11 years	56.4	47.0 (45.9–48.0)
12–17 years	43.6	53.0 (52.0–54.1)
Z scores		
Height Z	0.32	0.29 (0.23–0.34)
Weight Z	0.51	0.51 (0.44–0.57)
BMI Z	0.46	0.46 (0.40–0.52)
Waist Z	0.05	0.07 (0.01–0.13)
Waist—Height Ratio Z	−0.18	−0.15 (−0.21–−0.09)
Weight Status		
OW/OB (%)	2,292 (31.0)	31.1 (28.9–33.3)
OB (%)	937 (12.7)	13.0 (11.6–14.5)
BP variables		
2004 BP percentile		
SBP	22.2	21.3 (20.4–22.1)
DBP	47.2	45.9 (44.8–47.1)
2017 BP percentile		
SBP	25.3	24.2 (23.3–25.2)
DBP	47.7	46.4 (45.3–47.6)
2004 BP (%)		
Normal	7,008 (94.9)	95.5 (94.8–96.1)
Prehypertension	197 (2.7)	2.6 (2.1–3.2)
Stage 1	143 (1.9)	1.5 (1.2–2.0)
Stage 2	39 (0.5)	0.4 (0.3–0.6)
'High BP'	379 (5.1)	4.5 (3.9–5.2)
2017 BP (%)		
Normal	6,872 (93.4)	94.2 (93.4–95.0)
Elevated	180 (2.4)	2.1 (1.7–2.7)
Stage 1	238 (3.2)	2.9 (2.4–3.6)
Stage 2	66 (0.9)	0.7 (0.5–1.0)
'High BP'	484 (6.6)	5.8 (5.0–6.6)
Reclassified BP (%)	261 (3.5)	3.3 (2.7–4.0)

Mean (95% CI) for continuous variables; count (%, 95% CI) for categorical variables.

BMI Body mass index; CI Confidence interval; BP Blood pressure; DBP Diastolic BP; OW/OB Overweight/obese; SBP Systolic BP; Z z-score.

Table 3. Social, economic, and lifestyle variables for the sample and population of included children ages 6–17 years from cycles 1–4 of the Canadian Health Measures Survey

Characteristics (N=7,387)	Sample n (%)	Population (%)
Health/health care history		
Has a regular doctor	6,611 (89.6)	88.8 (87.0–90.4)
Immediate family history of high BP excluding pregnancy	5,883 (18.2)	17.0 (15.5–18.6)
Complain sick:		
Not true	4,975 (72.2)	72.6 (70.6–74.5)
Somewhat true	1,441 (20.9)	20.7 (19.2–22.2)
Certainly true	479 (7.0)	6.7 (5.8–7.7)
Has chronic health issue	2,006 (28.2)	29.2 (27.2–31.2)
Socioeconomic status		
White ethnicity	5,617 (79.5)	76.8 (70.8–81.9)
Born in Canada	6,661 (90.2)	89.7 (87.0–91.9)
Education:		
High school or below	1,017 (14.1)	14.4 (12.7–16.3)
Above high school	6,177 (85.9)	85.6 (83.7–87.3)
Income:		
<$30 000	869 (11.8)	11.8 (10.1–13.8)
≥$30 000	6,518 (88.2)	88.2 (86.2–89.9)
Region:		
Ontario	2,634 (35.7)	40.2 (39.3–41.1)
Atlantic Canada	833 (11.3)	6.6 (6.3–7.0)
Quebec	1,843 (25.0)	22.3 (21.6–22.9)
Prairies	1,048 (14.2)	18.5 (17.7–19.3)
British Columbia	1,029 (13.9)	12.4 (11.6–13.3)
Lifestyle		
Salt added to food: Never/Rarely	5,345 (72.4)	71.3 (69.5–73.2)
Sometimes	1,233 (16.7)	16.8 (15.2–18.5)
Often	809 (11.0)	11.8 (10.6–13.1)
Sleep trouble:	2,400 (32.5)	31.7 (29.9–33.6)
Never		
Rarely	2,357 (31.9)	32.1 (30.4–33.9)
Sometimes	1,852 (25.1)	25.7 (24.0–27.4)
Most times	564 (7.2)	7.7 (6.8–8.7)
Always	212 (2.9)	2.8 (2.2–3.5)
Smoke in home	788 (10.7)	10.7 (9.3–12.4)
Exercise (6–11years, N=4,195): ≥4 days/week	3,417 (81.4)	81.2 (79.3–82.9)
2–3 days/week	586 (14.0)	13.7 (12.3–15.2)
0–1 days/week	192 (4.6)	5.1 (3.9–6.6)
Substance use (12+ years, N=3,174):		
Alcohol this year	1,139 (35.9)	35.8 (32.6–39.1)
Has ever smoked	169 (5.3)	5.8 (4.4–7.8)

Table 3 reveals that most Canadian children have access to healthcare, live in educated households, and have generally healthy lifestyles. Access to a regular doctor was high (88.8%). Although 29.2% of the population reported a chronic health issue, only 6.7% answered 'certainly true' when asked whether they perceived themselves as sick. Most (89.7%) were born in Canada. Three quarters were white (76.8%,); there were

high levels (85.6%) of high school completion, and 88.2% had annual household incomes ≥$30,000. In terms of lifestyle, 63.8% of Canadian children never or rarely had sleep problems. Most did not or rarely add salt to their food (71.3%), few lived in homes where people smoked (10.7%), and a majority of children 6–11 years exercised ≥4 days each week for over 60 minutes (81.2%).

In Table 4, children with high BP were younger than those with normal BP, with mean age 10.5 years versus 12.3 years. They were also heavier, with higher z-scores for BMI, waist circumference, and waist/height ratio. As a result, the proportion of children with obesity was higher at 20.4% with high BP versus 12.6% with normal BP, P<0.05. Using the 2017 BP charts, the mean SBP percentile was 75.1 for those with high BP versus 21.1 in those with normal BP, which was more striking than the discrepancy for DBP. Household smoking was also significantly higher: 17.3% in those with high BP versus 10.3% in those with normal BP. The same was true for abnormal triglycerides at 16.1% versus 9.9%, respectively (Table 5).

Birth history (Supplementary Table S1) was similar between groups, except maternal smoking while pregnant, which was significantly higher in those with high BP (19.3% versus 13.1%, P=0.03). Breastfeeding exposure did not differ.

DISCUSSION

Although the impact of the new 2017 AAP reference charts has been studied in other jurisdictions (6,28–33), to our knowledge, this is the first to examine a nationally representative sample outside of the USA. The impact of the new norms appears to be more modest in Canada, with an increase in the population prevalence of high BP from 4.5 to 5.8%. Although both SPB and DBP percentiles experienced a significant upward shift with the 2017 norms, this shift was also more modest and affected SBP percentiles primarily (mean discrepancy +3.0, 95% LOA=−2.0 to +12.0). In our previous analysis of NHANES data, SBP bias was +5.3 (LOA=−1.0 to 13.0), and 86% of those with high BP experienced isolated systolic elevation (6). Although long-term follow-up studies are needed to better define cardiovascular risk, the current AAP approach to risk stratification relies on alignment with adult cut-offs at age 19 years, since childhood BP tracks into adulthood, and children with elevated BP are more likely to develop primary hypertension and metabolic syndrome (34,35).

As reviewed elsewhere (3,15,36), the epidemiology of childhood hypertension is complex: Compared to normotensive children, Canadian children with high BP tend to be younger and are more likely to be OW/OB, experience both in utero and household smoking exposure, and have elevated triglycerides. They also had higher weight, waist, and BMI z-scores. Pertinent negatives should also be noted: Exercise frequency, added

Table 4. Normal BP versus high BP using 2017 guidelines for population for children aged 6–17 years from cycles 1–4 of the Canadian Health Measures Survey

Characteristics	Normal BP (2017)	High BP (2017)
Biological determinants		
Male sex %	51.8 (50.8–52.3)	53.1 (45.0–61.2)
Age (years)	12.3 (12.2–12.4)	10.5 (9.85–11.1)***
6–11 years. age %	45.7 (44.4–46.9)	69.8 (61.4–78.3)***
Z scores		
Height Z	0.30 (0.24–0.35)	0.16 (0.0081–0.30)
Weight Z	0.50 (−0.050–0.53)	0.73 (0.46–1.02)
BMI Z	0.45 (0.38–0.51)	0.76 (0.39–1.022)*
Waist Z	0.06 (0.01–0.12)	0.20 (0.0040–0.39)
Waist–Height Ratio Z	−0.16 (−0.22–0.10)	0.093 (−0.11–0.16)*
BP variables		
2004 BP percentile:		
SBP	18.3 (17.5–19.2)	69.0 (65.6–72.4)***
DBP	43.3 (42.1–44.4)	89.4 (87.1–91.5)***
2017 BP percentile:		
SBP	21.1 (20.2–22.1)	75.1 (71.8–78.5)***
DBP	43.7 (42.5–44.9)	91.5 (89.1–93.9)***
Weight Status		
OW/OB (%):	30.6 (28.4–32.8)	39.4 (31.4–47.4)*
Obese (%)	12.6 (11.0–14.1)	20.4 (12.3–28.4)*
Health/healthcare history		
Has chronic health issue	28.7 (26.8–30.6)	34.1 (26.5–41.2)
Has a regular doctor	88.6 (87.0–90.3)	90.9 (85.5–96.2)
Immediate family member had high BP excluding in pregnancy	16.7 (15.2–18.3)	21.2 (15.1–27.3)
Complain sick:		
Not true	73.0 (70.9–75.1)	66.0 (59.4–72.6)
Somewhat true	20.4 (18.8–22.0)	24.5 (19.0–30.1)
Certainly true	6.5 (5.5–7.5)	9.5 (4.9–14.0)
Socioeconomic status		
White Ethnicity (vs. not)	76.9 (71.3–82.5)	79.8 (72.0–87.5)
Born in Canada (vs. not)	89.5 (86.9–92.1)	93.5 (90.3–96.7)
Education ≤high school (vs. >high school)	14.2 (12.5–15.9)	18.6 (12.6–24.5)
Income <$30,000 (vs. ≥$30,000)	11.7 (9.7–13.6)	13.9 (8.6–19.3)

Table 4. Continued

Characteristics	Normal BP (2017)	High BP (2017)
Biological determinants		
Region:		
Ontario	40.2 (39.3–41.2)	37.2 (30.1–44.3)
Atlantic Canada	6.7 (6.3–7.0)	6.3 (1.5–11.1)
Quebec	22.2 (21.6–22.9)	24.2 (18.9–29.4)
Prairies	18.3 (17.2–19.4)	22.3 (17.1–27.4)
British Columbia	12.6 (11.6–13.6)	10.0 (6.1–13.9)
Lifestyle		
Salt added to meals: Never/Rarely	71.0 (69.0–72.8)	77.4 (70.7–84.1)
Sometimes	16.9 (15.2–18.6)	15.6 (9.5–21.7)
Often	12.1 (10.8–13.5)	7.0 (3.1–10.9)
Exercise (6–11 years): ≥4 days/week	81.3 (79.3–83.2)	80.8 (75.5–86.0)
2–3 days/week	13.6 (12.0–15.1)	15.6 (10.8–20.3)
0–1 days/week	5.2 (3.7–6.6)	3.7 (1.6–5.7)
Sleep trouble:		
Never	31.6 (29.7–33.4)	34.4 (27.0–41.7)
Rarely	32.2 (30.5–34.0)	30.9 (25.4–36.4)
Sometimes	25.6 (23.9–27.4)	25.0 (18.2–31.9)
Most times	7.8 (6.8–8.8)	6.8 (3.7–9.8)
Always	2.8 (2.1–3.5)	2.9 (-0.3–6.1)
Smoke in the home	10.3 (8.8–11.2)	17.3 (12.1–22.5)**

Results are population means and prevalence (95% confidence intervals) based on inverse probability survey weights and bootstrap weights. In the sample, N=6,903 with normal BP and N=484 with high BP.

BMI Body mass index; BP Blood pressure; DBP Diastolic BP; OW/OB Overweight/obese; SBP Systolic BP; Z z-score.

*P<0.05, **P<0.01, ***P<0.001.

dietary salt, neonatal intensive care stay, and breastfeeding did not appear to differ between groups. Canadian children were overall quite healthy, with a slightly larger proportion of those with high BP reporting chronic health issues based on a variety of conditions, including behavioural, mental health, and common childhood diseases.

The finding of high BP at a single visit must normally be confirmed over multiple visits (3,4,7). In a recent survey of students aged 10 to 17 years in Houston, the initial prevalence of high BP using AAP standards was 29.4%, declining to 19.7% after three visits. For stage 1 and 2 hypertension, corresponding figures were 14.6% on initial screen, subsequently declining to 2.3% (33). Nevertheless, a diagnosis of high BP has important ramifications, since additional follow-up and treatment are required whenever single-visit BP values are consistent with levels seen in elevated BP, stage 1 hypertension, or stages 2 hypertension (3,7). For elevated BP levels, life-style modifications (healthy diet, sleep, and physical activity) are recommended, and the BP is to be reassessed by auscultation after 6 months instead of 1 year. In addition to lifestyle changes, asymptomatic children with stage 1 levels should be reassessed by auscultation in 1 to 2 weeks, and those with stage 2 levels require more urgent evaluation or referral to a subspecialist within the week. Persistent elevation may prompt additional evaluation (e.g., echocardiography or 24-hour ambulatory monitoring) or treatment. Clearly, a worsening clinical stage represents a real burden for the child, family, and health care system.

Both NHANES and CHMS rely on similar, national, multistage sampling designs; nevertheless, the difference in prevalence was dramatic. In US children aged 5 to 18 years, we previously reported an increase in the prevalence of high BP from 11.8% (11.1 to 13.0) using 2004 guidelines to 14.2% (13.4 to 15.0) using 2017 guidelines—more than 2.5 times the comparable figures here. Similarly, the proportion of the population reclassified upwards was also higher in the USA at 5.9% (5.4 to 7.0) (6).

If real, these differences may reflect differences in national rates of childhood OW/OB (6,8,9). The population prevalence of obesity in Canadian children (Table 2) was 13.0%, and the OW/OB rate was 31.1%. In US children, we have previously reported an obesity rate of 19.5% (18.7 to 20.0), with OW/OB in 40.6% (39.5 to 42.0) using the same WHO charts (6).

In terms of study strengths and limitations, the CHMS is a well-characterized, representative, national population survey (8–10,37). Survey weights permit reliable population estimates, including standard errors and confidence limits (23,24). Nevertheless, privacy concerns and cell-size restrictions preclude certain analyses, for example, those based on region, age, or ethnicity. The comprehensive nature of the survey questionnaire also makes it possible to explore associated social, biological, and physical factors, although some questions could not be compared across cycles (e.g., screen time, fluid consumption, and exercise frequency in children >11 years of age).

Measurement methods must be considered when comparing the two countries. The 2004 and 2017 reference charts and NHANES rely on sphygmomanometry with auscultation, still considered the gold standard (4–6). With oscillometric devices, differences in proprietary algorithms may complicate quantitative comparisons, particularly in children (38). Nevertheless, the BPTru device used by CHMS has been independently validated and endorsed by the American Heart Society, the British and Irish Hypertension Societies, Hypertension Canada, the Canadian Hypertension Education Program, and the Canadian Agency for Drugs and Technologies

Table 5. Descriptive lab values for the sample and population and comparison of normal BP versus high BP for population (2017 American Academy of Pediatrics)

Analytes	Sample	Population	Normal BP (2017)	High BP (2017)
Hemoglobin A1c (A1C, mmol/mol), N=6,608	34.4	34.4 (33.3–35.5)	34.4 (34.3–35.5)	34.4 (33.3–35.5)
Abnormal HbA1c (%): >37.7, N=6,608	1,138 (17.2)	15.8 (10.1–23.9)	16.3 (11.2–21.4)	13.1 (4.5–21.8)
Cholesterol (mmol/L)N=6,827	4.07	4.06 (4.03–4.10)	4.06 (4.02–4.10)	4.11 (3.99–4.23)
Abnormal cholesterol (%): ≥5.18 mmol/L, N=6,827	489 (7.2)	7.8 (6.7–9.0)	7.8 (6.7–8.9)	8.7 (5.0–12.4)
HDL (mmol/L)N=6,827	1.38	1.36 (1.34–1.38)	1.36 (1.34–1.38)	1.36 (1.31–1.41)
Abnormal HDL (%): <1.04 mmol/L, N=6,827	814 (11.9)	13.2 (11.6–15.2)	12.4 (10.1–14.7)	11.7 (5.1–18.3)
LDL (mmol/L)N=3,257	2.26	2.27 (2.20–2.34)	2.27 (2.19–2.34)	2.35 (2.21–2.50)
Abnormal LDL (%): ≥3.37 mmol/L, N=3,257	160 (4.9)	4.9 (3.2–7.2)	4.9 (2.9–6.9)	4.6 (0.4–8.8)
Creatinine (μmol/L)N=6,814	52.2	53.8 (53.1–54.5)	54.0 (53.3–54.7)	50.9 (48.1–53.7)
Triglycerides (mmol/L)N=3,257	0.88	0.89 (0.85–0.93)	0.89 (0.85–0.93)	0.92 (0.81–1.0)
Abnormal triglycerides (%):≤9 years: ≥1.13 mmol/L >9 years: ≥1.47 mmol/LN=3,257	340 (10.4)	10.3 (8.0–13.2)	9.9 (7.4–12.4)	16.1 (8.9–23.4)*

Results are population means and prevalence (95% confidence intervals) based on inverse probability survey weights and bootstrap weights. In the sample, N=6903 with normal BP and N=484 with high BP.

BP Blood pressure; mmol/L Millimoles/liter; μmol/L Micromoles/liter; mmol/mol Millimoles/mole; HDL High-density lipoprotein cholesterol; LDL Low-density lipoprotein cholesterol; Hb = Hemoglobin, as in HbA1c =glycosylated hemoglobin.

*P<0.05, P value.

in Health. In Canada, the British Columbia Ministry of Health names it as their preferred automated office method for accuracy and accessibility (14). To our knowledge, only one study has specifically looked at performance in children, concluding that accuracy meets the British Hypertension Society's 'Grade A' standard for both SBP and DBP agreement, with superior performance for SBP (13).

In conclusion, this study is the first to explore the new AAP guidelines in a nationally representative study outside of the USA and clearly demonstrates the need for similar studies in other jurisdictions before extrapolating from the US experience. Comparing the new AAP guidelines to their 2004 predecessor, Canadian children show an upward shift in BP percentiles, more marked for SBP. As a result, 5.8% of children aged 6 to 18 years have high BP, often associated with other cardiac risk factors, such as OW/OB, elevated serum triglycerides, and in utero and household smoking exposure. Despite differences in measurement methods, the prevalence of high BP appears lower than in the USA (14.2%, 5 to 18 years). Although other explanations cannot be ruled out, these differences may at least in part be due to differences in rates of OW/OB in the two countries. More importantly, this suggests that high BP in childhood may be preventable, with important implications for public health strategies.

SUPPLEMENTARY DATA

Supplementary data are available at *Paediatrics & Child Health* Online.

ACKNOWLEDGEMENTS

This work was supported by the Children's Hospital Research Institute of Manitoba and performed in the Statistics Canada Research Data Centre at the University of Manitoba.

Author contributions: All authors made substantial contributions to the conception, design, interpretation of the data, drafting the manuscript and provided final approval of this submitted version. SKR and AKS undertook all the analyses.

Funding: There are no funders to report for this submission.

Potential Conflicts of Interest: All authors: No reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

References

1. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: A report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol 2018;71(19):e127–248.
2. Muntner P, Carey RM, Gidding S, et al. Potential U.S. population impact of the 2017 ACC/AHA high blood pressure guideline. J Am Coll Cardiol 2018;71(2):109–18.
3. Flynn JT, Kaelber DC, Baker-Smith CM, et al. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. Pediatrics. 2017;140(3):e20171904.
4. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics. 2004;114(2 Suppl 4th Report):555–76.
5. Rosner B, Cook N, Portman R, Daniels S, Falkner B. Determination of blood pressure percentiles in normal-weight children: Some methodological issues. Am J Epidemiol 2008;167(6):653–66.
6. Sharma AK, Metzger DL, Rodd CJ. Prevalence and severity of high blood pressure among children based on the 2017 American Academy of Pediatrics Guidelines. JAMA Pediatr 2018;172(6):557–65.

7. Dionne JM, Harris KC, Benoit G, et al.; Hypertension Canada Guideline Committee. Hypertension Canada's 2017 Guidelines for the diagnosis, assessment, prevention, and treatment of pediatric hypertension. Can J Cardiol 2017;33(5):577–85.
8. Rodd C, Sharma AK. Recent trends in the prevalence of overweight and obesity among Canadian children. CMAJ 2016;188(13):E313–20.
9. Rodd C, Sharma AK. Prevalence of overweight and obesity in Canadian children, 2004 to 2013: Impact of socioeconomic determinants. Paediatr Child Health 2017;22(3):153–8.
10. Bryan S, St-Denis M, Wojtas D. Canadian Health Measures Survey: Clinic operations and logistics. Health Rep 2007;18 (Suppl):53–70.
11. Statistics Canada. Canadian Health Measures Survey (CHMS) Data User Guide: Cycles 1–4. Ottawa, ON: Statistics Canada; 2017. (Canadian Health Measures Survey Data User Guides).
12. Government of Canada SC. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 1. 2014. https://www.statcan.gc.ca/eng/statistical-programs/document/5071_D2_T1_V1 (Accessed January 9, 2020).
13. Mattu GS, Heran BS, Wright JM. Overall accuracy of the BpTRU–an automated electronic blood pressure device. Blood Press Monit 2004;9(1):47–52.
14. Hypertension – Diagnosis and Management. https://www2.gov.bc.ca/assets/gov/health/practitioner-pro/bc-guidelines/htn-full-guideline.pdf (Accessed July 18, 2019).
15. Paradis G, Tremblay MS, Janssen I, Chiolero A, Bushnik T. Blood pressure in Canadian children and adolescents. Health Rep 2010;21(2):15–22.
16. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007;85(9):660–7.
17. Rodd C, Metzger DL, Sharma A; Canadian Pediatric Endocrine Group (CPEG) Working Committee for National Growth Charts. Extending World Health Organization weight-for-age reference curves to older children. BMC Pediatr 2014;14:32.
18. Sharma AK, Metzger DL, Daymont C, Hadjiyannakis S, Rodd CJ. LMS tables for waist-circumference and waist-height ratio Z-scores in children aged 5-19 y in NHANES III: Association with cardio-metabolic risks. Pediatr Res 2015;78(6):723–9.
19. Low income cut-offs (LICOs) before and after tax by community size and family size, in current dollars. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110024101 (Accessed July 18, 2019).
20. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: Summary report. Pediatrics. 2011;128 (Suppl 5):S213–56.
21. American Diabetes Association. 2. Classification and diagnosis of diabetes. Diabetes Care. 2017;40 (Suppl 1):S11–24.
22. Hoelzel W, Weykamp C, Jeppsson JO, et al.; IFCC Working Group on HbA1c Standardization. IFCC reference system for measurement of hemoglobin A1c in human blood and the national standardization schemes in the United States, Japan, and Sweden: A method-comparison study. Clin Chem 2004;50(1):166–74.
23. StataCorp. Stata Statistical Software: Release 15. College Station, TX: StataCorpLLC; 2017.
24. Gagne C, Roberts G, Keown L-A. Weighted estimation and bootstrap variance estimation for analyzing survey data: How to implement in selected software. Res Data Cent Inf Tech Bull. 2014;6(1):1–72.
25. R Shiny: Growth charts and z-score calculators. 2017. http://apps.cpeg-gcep.net/ (Accessed March 23, 2020).
26. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1(8476):307–10.
27. Lumley T. Complex surveys: A guide to analysis using R. Hoboken, NJ: Wiley and Sons; 2010. (Wiley Series in Survey Methodology).
28. Jackson SL, Zhang Z, Wiltz JL, et al. Hypertension among youths - United States, 2001-2016. MMWR Morb Mortal Wkly Rep 2018;67(27):758–62.
29. Al Kibria GM, Swasey K, Sharmeen A, Day B. Estimated change in prevalence and trends of childhood blood pressure levels in the United States after application of the 2017 AAP Guideline. Prev Chronic Dis 2019;16:E12.
30. Shipp EM, Cooper SP, Jiang L, Trueblood AB, Ross J. Influence of work on elevated blood pressure in Hispanic adolescents in South Texas. Int J Environ Res Public Health. 2019;16(7):1–12.
31. Kharbanda EO, Asche SE, Dehmer SP, et al. Impact of updated pediatric hypertension guidelines on progression from elevated blood pressure to hypertension in a community-based primary care population. J Clin Hypertens (Greenwich) 2019;21(5):560–5.
32. Dong Y, Song Y, Zou Z, Ma J, Dong B, Prochaska JJ. Updates to pediatric hypertension guidelines: Influence on classification of high blood pressure in children and adolescents. J Hypertens 2019;37(2):297–306.
33. Bell CS, Samuel JP, Samuels JA. Prevalence of hypertension in children. Hypertension 2019;73(1):148–52.
34. Sun SS, Grave GD, Siervogel RM, Pickoff AA, Arslanian SS, Daniels SR. Systolic blood pressure in childhood predicts hypertension and metabolic syndrome later in life. Pediatrics 2007;119(2):237–46.
35. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: A systematic review and meta-regression analysis. Circulation 2008;117(25):3171–80.
36. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: The NHANES experience 1988-2008. Hypertension 2013;62(2):247–54.
37. Rodd C, Feely A, Dart A, Sharma A, McGavock J. Biological and socioeconomic determinants of prediabetes in youth: An analysis using 2007 to 2011 Canadian Health Measures Surveys. Pediatr Res 2018;84(2):248–53.
38. Miranda JJ, Stanojevic S, Bernabe-Ortiz A, Gilman RH, Smeeth L. Performance of oscillometric blood pressure devices in children in resource-poor settings. Eur J Cardiovasc Prev Rehabil 2008;15(3):362–4.