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ABSTRACT

Background

To date, population estimates of hypertension prevalence among children and adolescents in Canada have been based on clinical guidelines in the National High Blood Pressure Education Program's 2004 *Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* (NHBPEP 2004). In 2017, the American Academy of Pediatrics published updated guidelines in *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* (AAP 2017), followed by Hypertension Canada in 2020 with its publication of *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* (HC 2020). This study compares national child and adolescent hypertension prevalence estimates based on NHBPEP 2004, AAP 2017 and HC 2020.

Data and methods

Six cycles of data spanning 2007 to 2019 from the Canadian Health Measures Survey were used to compare blood pressure (BP) categories and the prevalence of hypertension by sex and age group under all sets of guidelines for children and adolescents aged 6 to 17. The impact of applying AAP 2017 across time and selected characteristics, the resulting reclassification into a higher BP category under AAP 2017, and differences in hypertension prevalence resulting from applying HC 2020 versus AAP 2017 were examined.

Results

Prevalence of Stage 1 hypertension was higher among children and adolescents aged 6 to 17 under AAP 2017 and HC 2020 than under NHBPEP 2004. Overall hypertension prevalence was also higher, and obesity was a major factor associated with being reclassified into a higher BP category under AAP 2017.

Interpretation

Implementation of AAP 2017 and HC 2020 is associated with significant changes in the epidemiology of hypertension. Understanding the impact of applying updated clinical guidelines may help inform population surveillance efforts to track hypertension prevalence among Canada's children and adolescents.

Keywords

blood pressure, epidemiology, hypertension, pediatrics, prehypertension, prevalence

AUTHORS

Tracey Bushnik is with the Health Analysis Division, Statistics Canada. Thomas Ferrao is with the Centre for Population Health Data, Statistics Canada, and Alexander A. Leung is with the Department of Medicine and the Department of Community Health Sciences, University of Calgary.

What is already known on this subject?

- Diagnosing high blood pressure as early in life as possible is important because of the increased subsequent risk of adult hypertension, left ventricular hypertrophy and metabolic syndrome.
- To date, population estimates of hypertension prevalence among children and adolescents in Canada have been based on clinical blood pressure guidelines recommended in the National High Blood Pressure Education Program's 2004 *Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* (NHBPEP 2004).
- The American Academy of Pediatrics published updated guidelines in 2017 in *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* (AAP 2017), followed by Hypertension Canada with its publication of *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* (HC 2020) in 2020.
- Studies have found that the implementation of AAP 2017 is associated with significant changes in the epidemiology of hypertension.

What does this study add?

- To the authors' knowledge, this is the first study in Canada to compare the national estimates of the prevalence of child and adolescent hypertension based on AAP 2017 with estimates of prevalence based on NHBPEP 2004 and HC 2020.
- The prevalence of Stage 1 hypertension was higher among children and adolescents aged 6 to 17 under AAP 2017 and HC 2020 than under NHBPEP 2004 and higher among those aged 13 to 17 under AAP 2017 than under HC 2020 and NHBPEP 2004.
- Under AAP 2017, overall hypertension prevalence (Stage 1 and Stage 2 hypertension combined) was higher, and obesity was a major factor associated with being reclassified to a higher blood pressure category.
- Understanding the impact of applying updated clinical guidelines may help inform population surveillance efforts to track hypertension prevalence among Canada's children and adolescents.

Studies have found that elevated blood pressure (BP) in childhood increases the risk for adult high BP and hypertension.[1-3] Hypertension affects almost one in four Canadian adults[4] and is considered a leading risk factor for cardiovascular disease and premature death worldwide.[5] It is also the leading risk factor for attributable disability-adjusted life years globally among those aged 50 or older.[6]

The Canadian Health Measures Survey (CHMS) has been used to produce and monitor national population estimates of BP among Canadian children and adolescents since 2007. The CHMS currently categorizes children and adolescents into BP categories based on clinical guidelines recommended in the National High Blood Pressure Education Program's *Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents*, published in 2004,[7] referred to as NHBPEP 2004. Over the past few years, the American Academy of Pediatrics (AAP) and Hypertension Canada (HC) have published separate updates to NHBPEP 2004. The 2017 AAP update, *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* (AAP 2017),[8] includes revised normative pediatric BP tables, replaces the term "prehypertension" with "elevated BP," and recommends a new definition of Stage 2 hypertension and a simplified BP classification in adolescents aged 13 years or older. HC's 2020 update, *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* (HC 2020),[9] defines Stage 1 and Stage 2 hypertension for children and adolescents similarly to AAP 2017, but not identically. There is currently no consensus on which updated guidelines are most appropriate for Canadian clinical practice,[10] but it is believed that many clinicians in Canada now refer to the AAP 2017 or HC 2020 recommendations.

Prevalence estimates of childhood hypertension at the population level serve to quantify and track the potential burden of this health problem. Epidemiological studies of children and adolescents in the United States, Europe and China that have compared NHBPEP 2004 with AAP 2017 found a higher estimated prevalence of hypertension under AAP 2017.[11-15] In Canada, the potential impact of applying AAP 2017 to produce national estimates of hypertension

among children and adolescents has yet to be assessed. Moreover, the population prevalence of hypertension under HC 2020 and how it compares with AAP 2017 and NHBPEP 2004 is currently unknown.

The main objectives of this analysis are to apply AAP 2017 and HC 2020 to all six cycles of CHMS data available to date and examine the effect on population estimates of hypertension prevalence by sex and age group among children and adolescents aged 6 to 17. This study also examines the impact of applying AAP 2017 across time and selected characteristics, describes those who are reclassified into a higher BP category under AAP 2017, and examines differences in hypertension prevalence resulting from applying HC 2020 versus AAP 2017.

Methods

Data source

The data are from the first (2007 to 2009), second (2009 to 2011), third (2012 to 2013), fourth (2014 to 2015), fifth (2016 to 2017) and sixth (2018 to 2019) cycles of the CHMS. The CHMS is a cross-sectional survey that collects questionnaire and directly measured health information from community-dwelling individuals aged 3 to 79 (aged 6 to 79 in Cycle 1) living in the 10 provinces. People living in the three territories or on reserves and settlements in the provinces, the institutionalized population, residents of certain remote regions, and full-time members of the Canadian Forces are excluded (about 4% of the Canadian population).

The CHMS involves an in-person household interview and a subsequent visit to a mobile examination centre (MEC). From each household selected for the CHMS, one member is randomly chosen to complete the survey. If that individual is younger than 12, an older member of the same household is also chosen to participate. The household interview gathers general demographic and socioeconomic data and detailed information on health, nutrition and lifestyle. For respondents younger than 12, the questions are answered by the second household respondent aged 12 to 79. At the MEC, direct physical measurements are taken, including BP, height, weight and waist circumference. Information about the CHMS is available online.[16]

Cycle 1 collected information from Canadians aged 6 to 79 and had an overall response rate of 51.7%—a total of n = 5,604 respondents. Cycles 2, 3, 4, 5 and 6 collected information from Canadians aged 3 to 79, and the overall response rates were 55.5% (n = 6,395), 51.7% (n = 5,785), 53.7% (n = 5,794), 48.5% (n = 5,786) and 45.9% (n = 5,797), respectively. Participants from one cycle were not eligible to participate in other cycles. The present study combined 6- to 17-year-old participants from each cycle for a total of 11,138 respondents. Respondents who reported being pregnant (n = 4) or had insufficient data to derive a BP classification (n = 70) were excluded. The final analytical sample size was 11,064.

Measures and definitions

Blood pressure: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured with the BpTRU™ BPM-300 automated oscillometric device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia) at the MEC. Six BpTRU™ readings were taken for each CHMS participant, with the last five averaged to determine the SBP and DBP levels.[17] Seven respondents in the analytical sample who did not visit the MEC had their BP measured with the BpTRU™ BPM-100 device during the home interview.

Measured SBP and DBP were compared with sex-, age- and height-specific SBP and DBP percentiles to classify respondents into separate BP categories. Appendix Table 1 presents the classifications under NHBPEP 2004, AAP 2017 and HC 2020.

NHBPEP 2004 has the following BP categories: normal, prehypertension, Stage 1 hypertension and Stage 2 hypertension. This categorization is included in the CHMS data files as the variable BPMDBPK.

AAP 2017 defines BP categories as normal, elevated BP, Stage 1 hypertension and Stage 2 hypertension. They were derived for this analysis using the childhood BP macro and accompanying data files—including the updated normative pediatric BP tables—published online by Dr. B. Rosner (available at https://sites.google.com/a/channing.harvard.edu/bernardrosner/pediatric-blood-press/childhood-blood-pressure).

HC 2020 does not explicitly define normal and elevated BP but uses percentile criteria to define Stage 1 and Stage 2 hypertension for children and adolescents. The updated normative pediatric BP tables used to derive AAP 2017 were also used to derive Stage 1 and Stage 2 hypertension under HC 2020.

Hypertension: Under all sets of guidelines, hypertension was Stage 1 and Stage 2 hypertension combined.

Normotensive: A respondent was considered normotensive if they were categorized as having normal BP under NHBPEP 2004 and AAP 2017.

Upward reclassification: A respondent was upwardly reclassified if they moved up a BP classification after applying AAP 2017, compared with their BP classification under NHBPEP 2004.

Height: Height was measured to the nearest 0.1 centimetre using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, United States).

Height category: Measured height was compared with sex- and age-specific height percentiles based on the Centers for

Disease Control Growth Charts[18] in the childhood BP macro provided by Dr. B. Rosner (available at https://sites.google.com/a/channing.harvard.edu/bernardrosner/pediatric-blood-press/childhood-blood-pressure). Five height categories were derived from the z-scores produced by the macro: low (z-score ≤ -2.0), low-middle (-2.0 < z-score ≤ -1.0), middle (-1.0 < z-score ≤ 1.0), high-middle (1.0 < z-score < 2.0) and high (z-score ≥ 2.0).

Weight: Weight was measured to the nearest 0.1 kilogram with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada).

Body mass index (BMI): BMI was calculated as measured weight in kilograms divided by measured height in metres squared. BMI categories were derived from the respondent's BMI-for-age-and-sex z-score based on a set of cut-offs specified by the World Health Organization.[19]

Waist circumference (WC): WC was measured to the nearest 0.1 centimetre, directly on the landmarked skin with a flexible, inelastic measuring tape with a tension meter attached. In keeping with the National Institutes of Health (NIH) protocol[20] that was implemented in Cycle 2, the measure was taken at the highest point of the iliac crest. A correction factor was applied to the WC measurements from Cycle 1 to ensure comparability with the NIH protocol measurements from all subsequent cycles.[21]

Central obesity: Waist-to-height ratio (WHtR) is a measure of fat distribution and primarily identifies those with abdominal obesity.[22] It was calculated as measured WC in centimetres divided by measured height in centimetres. Central obesity categories corresponded to not at risk (WHtR below 0.5), at risk (WHtR from 0.50 to less than 0.55) and high probability (WHtR at or above 0.55).[23]

Covariates

Sex (male or female) was confirmed at the visit to the MEC. Age group (6 to 12 or 13 to 17) was based on the age at the time of the visit to the MEC. Place of birth (born in Canada or not born in Canada) was reported during the household interview by the respondent if aged 12 or older, or by proxy if younger than 12.

Data were missing for some measures and covariates: BMI (n = 6), central obesity (n = 28) and place of birth (n = 1).

Statistical analysis

Proportions and 95% confidence intervals (CIs) were estimated to examine the distribution across BP categories and prevalence of hypertension under all sets of guidelines for children (aged 6 to 12) and adolescents (aged 13 to 17) by sex, together and separately. The CHMS sample design of collection sites selected within regions results in a limited number of degrees of freedom (df) available for variance estimation. Cycles 1, 3, 4, 5 and 6 each have 11 df available; Cycle 2 has 13 df. When the six cycles of data were pooled, 68 df were specified in all procedure statements.[24] Single-cycle analyses were weighted using the cycle-specific survey weight; all pooled analyses were weighted using a combined survey weight for cycles 1 to 6.[25] The combined replicate weights from cycles 1 to 6 were used for variance estimation (including 95% CIs) and significance testing of the pooled sample; cycle-specific replicate weights were used for single-cycle variance estimation. All analyses were conducted in SAS 9.4 and SAS-callable SUDAAN 11.0.3.

The DISCORDDIFF option in the SURVEYFREQ procedure in SAS provides the estimate of the difference between discordant proportions for 2 × 2 tables (also known as the McNemar test).[26] This option tests the null hypothesis that the discordant proportion difference is zero. For this analysis, it tested the null hypothesis at p = 0.05 that the change in proportion in a specific BP category between NHBPEP 2004 and AAP 2017 or HC 2020 was equal to zero. T-tests were used to test at p = 0.05 the null hypothesis that differences in proportions between reclassified upward and normotensive children and adolescents were equal to zero.

Results

Appendix Table 2 presents the sample size and weighted proportion distribution of children and adolescents across all BP categories and selected characteristics.

AAP 2017 versus NHBPEP 2004

Applying AAP 2017 resulted in a lower overall prevalence of normal BP and prehypertension or elevated BP, but a higher prevalence of Stage 1 hypertension, than with NHBPEP 2004 (Table 1). Under AAP 2017, 94.0% (95% CI: 93.3, 94.7) of children and adolescents aged 6 to 17 had normal BP, 2.1% (95% CI: 1.7, 2.6) had prehypertension or elevated BP, and 3.3% (95% CI: 2.9, 3.8) had Stage 1 hypertension, compared with 94.7% (95% CI: 94.2, 95.2), 2.7% (95% CI: 2.3, 3.2) and 2.1% (95% CI: 1.7, 2.5), respectively, under NHBPEP 2004. Similar differences were observed across age groups, except for the prehypertension or elevated BP category for children aged 6 to 12. The lower prevalence of normal BP under AAP 2017 was primarily observed among males in both age groups, while the higher prevalence of Stage 1 hypertension under AAP 2017 occurred for both males and females in both age groups. The overall prevalence of Stage 2 hypertension remained relatively unchanged, at 0.5%.

At all time points, the overall prevalence of hypertension (Stage 1 and Stage 2 combined) among children and adolescents was higher under AAP 2017 than under NHBPEP 2004 (Figure 1). The difference in prevalence under AAP 2017 ranged from 0.7 percentage points higher in Cycle 4 (2014 to 2015) to 1.8 percentage points higher in Cycle 5 (2016 to 2017) of the CHMS. With all six cycles of CHMS combined,

Table 1
Proportion distribution across blood pressure categories under NHBPEP 2004 and AAP 2017, by age group and by sex, 2007 to 2019

	Ages 6 to 17							Ages 6 to 12							Ages 13 to 17						
	NHBPEP 2004			AAP 2017				NHBPEP 2004			AAP 2017				NHBPEP 2004			AAP 2017			
		95% Confidence interval			95% Confidence interval				95% Confidence interval			95% Confidence interval				95% Confidence interval			95% Confidence interval		
	%	from	to	%	from	to	McNemar p-value	%	from	to	%	from	to	McNemar p-value	%	from	to	%	from	to	McNemar p-value
Total																					
Normal	94.7	94.2	95.2	94.0	93.3	94.7	0.00	92.6	91.7	93.3	91.8	90.9	92.7	0.00	97.6	96.6	98.3	97.0	95.8	97.8	0.03
Prehypertension or elevated BP	2.7	2.3	3.2	2.1	1.7	2.6	0.02	3.6	2.9	4.3	3.1	2.6	3.7	0.17	1.5	1.0	2.3	0.8	0.5	1.4	0.04
Stage 1 hypertension	2.1	1.7	2.5	3.3	2.9	3.8	0.00	3.0	2.5	3.5	4.3	3.7	4.9	0.00	0.9	0.5	1.7	2.1	1.4	3.1	0.00
Stage 2 hypertension	0.5	0.4	0.8	0.5	0.3	0.8	0.90	0.9	0.6	1.3	0.8	0.5	1.3	0.41	F	…	…	0.1	0.1	0.3	…
Males																					
Normal	95.3	94.6	95.9	93.9	92.8	94.8	0.00	93.6	92.5	94.6	92.0	90.6	93.2	0.00	97.5	96.0	98.4	96.4	94.4	97.8	0.05
Prehypertension or elevated BP	2.1	1.6	2.7	2.2	1.6	3.0	0.82	2.5	1.8	3.5	2.9	2.1	4.0	0.56	1.5	0.8	2.7	1.2	0.7	2.3	0.60
Stage 1 hypertension	2.0	1.5	2.6	3.3	2.7	4.0	0.00	2.6	2.1	3.4	4.1	3.3	5.1	0.00	1.0	0.5	2.2	2.1	1.2	3.7	0.02
Stage 2 hypertension	0.7	0.4	1.1	0.7	0.4	1.1	0.72	1.2	0.7	1.9	1.0	0.6	1.7	0.16	F	…	…	0.2	0.1	0.6	…
Females																					
Normal	94.2	93.2	95.0	94.2	93.2	95.0	0.95	91.4	90.0	92.7	91.6	90.2	92.9	0.26	97.8	96.2	98.7	97.5	95.9	98.5	0.26
Prehypertension or elevated BP	3.3	2.6	4.1	2.0	1.6	2.5	0.00	4.6	3.7	5.8	3.3	2.6	4.1	0.00	1.5	0.8	2.8	0.4	0.1	1.1	0.02
Stage 1 hypertension	2.2	1.7	2.9	3.4	2.7	4.2	0.00	3.3	2.5	4.4	4.4	3.5	5.5	0.01	0.7	0.3	2.0	2.1	1.2	3.6	0.00
Stage 2 hypertension	0.4	0.2	0.6	0.4	0.2	0.7	0.55	0.6	0.4	1.1	0.7	0.3	1.3	0.74	F	…	…	F	…	…	…

… not applicable

F too unreliable to be published

Notes: BP = blood pressure. NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017. NHBPEP 2004 defines four blood pressure categories: normal, prehypertension, Stage 1 hypertension and Stage 2 hypertension. AAP 2017 defines four blood pressure categories: normal, elevated, Stage 1 hypertension, and Stage 2 hypertension.

Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019, combined.

Table 2
Prevalence of hypertension under NHBPEP 2004 and AAP 2017 across selected characteristics, 2007 to 2019

	Ages 6 to 17						
	NHBPEP 2004			AAP 2017			
		95% Confidence interval			95% Confidence interval		McNemar
	%	from	to	%	from	to	p-value
Overall	2.6	2.2	3.1	3.9	3.4	4.4	0.0
Sex							
Male	2.6	2.1	3.3	3.9	3.3	4.7	0.0
Female	2.6	1.9	3.4	3.8	3.0	4.7	0.0
Born in Canada							
Yes	2.8	2.3	3.4	4.1	3.5	4.7	0.0
No	1.0	0.6	1.7	2.3	1.5	3.5	0.0
Body mass index category							
Neither overweight nor obese[1]	2.5	1.9	3.2	3.5	2.9	4.2	0.0
Overweight	2.9	2.0	4.0	3.8	2.9	5.1	0.0
Obese	2.2	1.3	3.6	4.7	3.1	7.1	0.0
Central obesity category							
Not at risk of central obesity	2.7	2.2	3.3	3.7	3.2	4.3	0.0
At risk	2.7	1.7	4.1	4.2	2.9	5.9	0.0
Centrally obese	1.9	1.1	3.3	5.0	3.2	7.7	0.0

[1] Excludes those whose measured body mass index (BMI) was less than or equal to two standard deviations below the mean BMI for age.

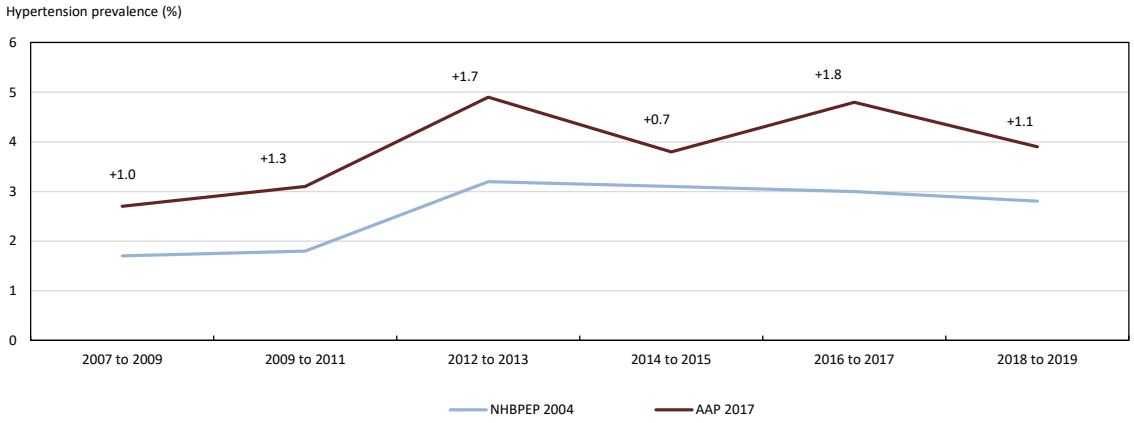
Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017; and CI = confidence interval. Hypertension is Stage 1 and Stage 2 hypertension categories combined.

Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019, combined.

the higher prevalence of hypertension under AAP 2017 persisted for 6- to 17-year-olds across sex, place of birth, ethnicity, BMI and central obesity categories (Table 2). The higher prevalence under AAP 2017 across these characteristics also held for children and adolescents separately, though some comparisons between the two sets of guidelines among adolescents could not be assessed because of insufficient sample sizes (data not shown). The difference in hypertension prevalence between males and females and between those born in and outside Canada was similar under both sets of guidelines. However, the proportion difference between obese and neither overweight nor obese increased from -0.3% under NHBPEP 2004 to 1.2% under AAP 2017. Similarly, the proportion difference between centrally obese and not at risk of central obesity increased from -0.8% under NHBPEP 2004 to 1.3% under AAP 2017. This increase in the proportion difference between these categories for the two measures was predominately among those aged 13 to 17 (data not shown).

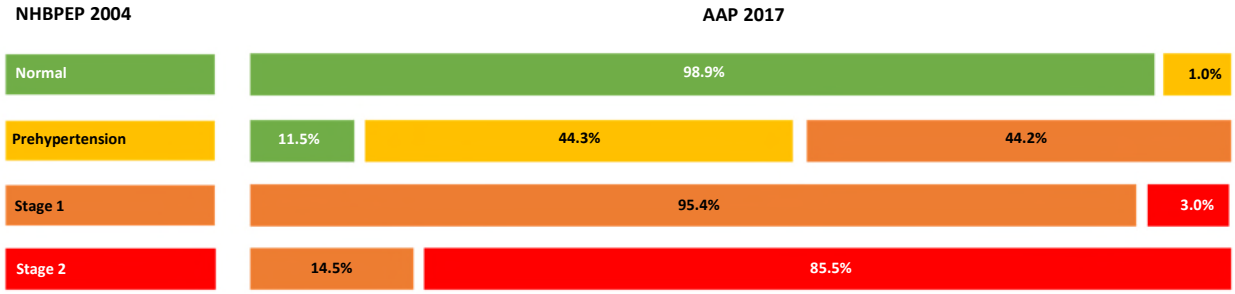
The higher overall prevalence of hypertension under AAP 2017 mainly reflected the upward reclassification of children and adolescents from prehypertension under

Figure 1
Prevalence of hypertension over time under NHBPEP 2004 and AAP 2017, children and adolescents aged 6 to 17, Canada, 2007-to-2009 period to 2018-to-2019 period



Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; and AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017. AAP 2017 versus NHBPEP 2004 McNemar test p-value < 0.05 at all time periods.
Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019.

Figure 2
Reclassification matrix from NHBPEP 2004 to AAP 2017, children and adolescents aged 6 to 17, Canada, 2007 to 2019



Notes: NHBPEP 2004 = The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents published by the National High Blood Pressure Education Program in 2004; AAP 2017 = Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents published by the American Academy of Pediatrics in 2017; and BP = blood pressure. Each row should be read from left to right. For example, 98.9% of those who were categorized as having normal BP under NHBPEP 2004 were also categorized as having normal BP under AAP 2017, 1.0% with normal BP under NHBPEP 2004 were reclassified upward to having elevated BP under AAP 2017.
Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019, combined.

NHBPEP 2004 to Stage 1 hypertension under AAP 2017. Figure 2 shows that of 6- to 17-year-olds who were categorized as having prehypertension under NHBPEP 2004, 44% were reclassified as having Stage 1 hypertension under AAP 2017. Moreover, 1% of those categorized as having normal BP under NHBPEP 2004 were reclassified as having elevated BP under AAP 2017, and 3% of those in Stage 1 were reclassified to Stage 2. By age group, the proportion reclassified upward from prehypertension under NHBPEP 2004 to Stage 1 hypertension under AAP 2017 was 34% among children and 76% among adolescents (data not shown).

Certain characteristics were more prevalent among those who were reclassified upward under AAP 2017 (Table 3). Compared with those who were normotensive, a significantly higher proportion of children and adolescents who were reclassified upward were male (64% versus 51%), obese (29% versus 12%) or centrally obese (26% versus 9%).

HC 2020 versus NHBPEP 2004 and AAP 2017

The overall prevalence of hypertension under HC 2020 (3.5%, 95% CI: 3.1, 4.1) was significantly higher than under NHBPEP 2004 but lower than under AAP 2017. Upward reclassification under HC 2020 occurred primarily from prehypertension to Stage 1 (data not shown). Stage 1 hypertension prevalence for 6- to 17-year-olds under HC 2020 was slightly lower than under AAP 2017, but significantly higher compared with NHBPEP 2004 (Figure 3). Stage 2 hypertension prevalence was unchanged from either NHBPEP 2004 or AAP 2017 (data not shown). The lower prevalence of Stage 1 hypertension under HC 2020 compared with AAP 2017 was observed only in the 13- to 17-year-old age group, predominantly among males (data not shown).

Table 3
Characteristics of children and youth reclassified upward under AAP 2017 versus those who remained normotensive, 2007 to 2019

	Reclassified upward			Normotensive			Difference		
		95% Confidence interval			95% Confidence interval			Confidence interval	
	%	from	to	%	from	to	%	from	to
Sex									
Male	64.2	54.3	72.9	51.3	50.4	52.1	12.9 ‡	3.3	22.5
Female	35.8	27.1	45.7	48.7	47.9	49.6	-12.9 ‡	-22.5	-3.3
Age group									
6 to 12	58.6	47.8	68.7	55.7	54.5	56.9	2.9	-7.9	13.7
13 to 17	41.4	31.3	52.2	44.3	43.1	45.5	-2.9	-13.7	7.9
Body mass index category									
Neither overweight nor obese[1]	49.2	37.7	60.7	68.1	66.3	69.9	-18.9 ‡	-30.6	-7.3
Overweight	17.7	12.0	25.4	18.1	16.8	19.4	-0.3	-7.0	6.3
Obese	28.9	18.7	41.8	11.7	10.6	13.0	17.2 ‡	5.2	29.2
Central obesity category									
Not at risk of central obesity	61.5	50.1	71.7	80.8	78.9	82.5	-19.3 ‡	-30.0	-8.5
At risk	12.9	7.7	20.7	10.6	9.5	11.8	2.3	-4.2	8.7
Centrally obese	25.6	15.9	38.6	8.6	7.6	9.8	17.0 ‡	5.6	28.4

‡ Indicates the difference between the estimate for reclassified upward and the estimate for normotensive statistically different from zero at $p < 0.05$.

[1] Excludes those whose measured body mass index (BMI) was less than or equal to two standard deviations below the mean BMI for age.

Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017; BP = blood pressure; and CI = confidence intervals. "Reclassified upward" includes all respondents who moved up at least one BP category from NHBPEP 2004 to AAP 2017. "Normotensive" includes all respondents who were classified as having normal BP under NHBPEP 2004 and AAP 2017.

Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019, combined.

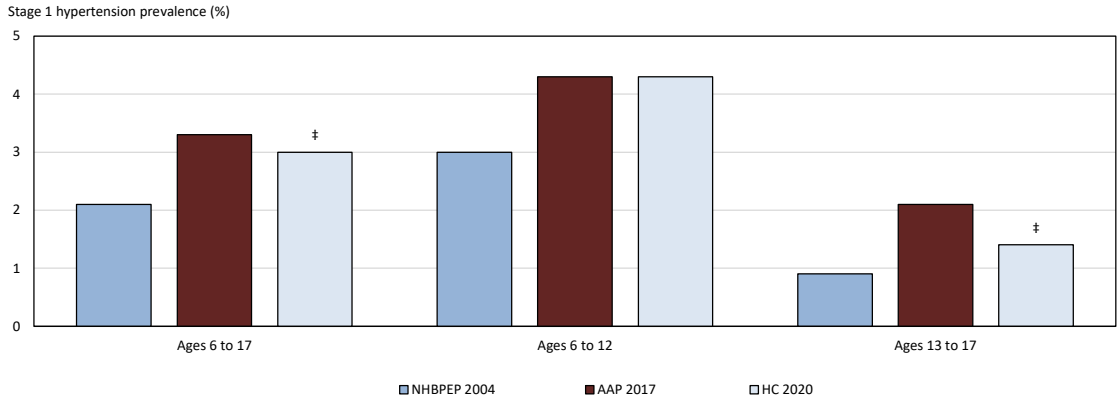
Discussion

Compared with NHBPEP 2004, this study found that applying AAP 2017 and HC 2020 was associated with significant changes in population estimates of pediatric hypertension. The prevalence of hypertension among Canadian children and adolescents was higher under both AAP 2017 and HC 2020, such that nearly 1 in 25 (formerly 1 in 40) people younger than 18 were considered hypertensive. This study also found that the prevalence of normal BP and prehypertension or elevated BP was lower and the prevalence of Stage 1 hypertension was higher among children and adolescents aged 6 to 17 under AAP 2017 and HC 2020 than under NHBPEP 2004, while Stage 2 hypertension prevalence remained relatively unchanged. Overall hypertension prevalence (Stage 1 and Stage 2 combined) under AAP 2017 was higher at all time points from Cycle 1 (2007 to 2009) to Cycle 6 (2018 to 2019) of the CHMS and across sex, place of birth, ethnicity, BMI and central obesity categories. Being male, obese or centrally obese was associated with being reclassified into a higher BP category under AAP 2017 than under NHBPEP 2004.

One of the key differences between AAP 2017 and NHBPEP 2004 is that the latter includes overweight and obese children in the reference population for its normative BP tables. Based on evidence of the strong association of being overweight or obese with elevated BP and hypertension, the AAP 2017 normative tables explicitly exclude children and adolescents in these body weight categories, with the aim of reducing bias.[8] Consequently, the BP values by age, sex and height in these tables—also referenced by HC 2020—are several millimetres of mercury (mmHg) lower than those suggested by NHBPEP 2004, resulting in more children and adolescents falling into higher SBP and DBP percentiles. This, coupled with slight changes to the SBP and DBP percentile thresholds categorizing children and adolescents into the various BP categories, has resulted in a systematically higher prevalence of hypertension under AAP 2017.[27]

Direct comparison of hypertension prevalence between studies can be challenging because the devices and methods used to measure BP often vary. Studies have shown that BP and hypertension prevalence estimates for children and adolescents based on measurements taken by an oscillometric device—as is the case in the present study—differ from estimates based on BP measured by auscultation.[28,29] It is still possible, however, to compare the relative impact of applying a new set of guidelines. In the present study, overall hypertension prevalence was higher under AAP 2017 than under NHBPEP 2004, regardless of sex and age group, and higher hypertension prevalence under AAP 2017 was observed at all time points between Cycle 1 (2007 to 2009) and Cycle 6 (2018 to 2019) of the CHMS. A higher prevalence of hypertension under AAP 2017 has been reported for boys and girls aged 6 to 12 and for boys aged 13 to 17 in China,[13] as has a higher hypertension prevalence under AAP 2017 for children aged 5 to 18 in the United States.[12] Using National Health and Nutrition Examination Survey data from 2005 to 2008 and 2013 to 2016 for children aged 8 to 17, Al Kibria et al. found

Figure 3
Stage 1 hypertension prevalence under NHBPEP 2004, AAP 2017 and HC 2020, by age group, Canada, 2007 to 2019



‡ HC 2020 versus AAP 2017 McNemar test p-value < 0.05
Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017; and HC 2020 = *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* published by Hypertension Canada in 2020.
Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019.

that applying AAP 2017 also resulted in a higher prevalence of hypertension at both time periods.[11]

The association between characteristics and the prevalence of hypertension in the present study did not change significantly under AAP 2017 except for characteristics related to body weight. Under NHBPEP 2004, there was very little difference in hypertension prevalence across body weight categories—likely reflecting that the BP normative tables at that time included overweight and obese individuals—but under AAP 2017, a more distinct pattern of a higher prevalence of hypertension corresponding to higher body weight emerged. This finding corresponds with what is known about the association between hypertension and adiposity[8] and is consistent with others who have reported that the positive gradient in hypertension prevalence was steeper across increasing body weight categories under AAP 2017.[13,15]

The observed overall increase in hypertension prevalence under AAP 2017 (and HC 2020) was mainly because of the reclassification of children and adolescents from prehypertension to Stage 1. A higher proportion of those who moved up a BP category were male, obese or centrally obese. The association between body weight and upward reclassification has been reported elsewhere.[12] Moreover, studies have found that not only are children and adolescents who have been reclassified upward under AAP 2017 more likely to have metabolic syndrome or left ventricular hypertrophy,[12,30] they are also more likely to develop these conditions and have a higher frequency of hypertension as adults.[31] These findings suggest that children and adolescents who are obese or have other cardiovascular risk factors are better classified as hypertensive under AAP 2017.[27]

Applying HC 2020 using the revised normative tables also produced a higher population prevalence of hypertension than NHBPEP 2004. However, the prevalence of Stage 1 hypertension was lower under HC 2020 than under AAP 2017, and this difference was driven by adolescents aged 13 to 17. AAP 2017 moved to absolute threshold values of SBP and DBP to define hypertension among adolescents 13 or older (130/80 mmHg or above), whereas HC 2020 uses percentile cut-offs (95th percentile plus 12 mmHg or above) for age, sex and height groupings; thus, adolescents whose BP is within the percentile threshold but meets or exceeds 130/80 mmHg are being categorized as hypertensive under AAP 2017 but not under HC 2020.

Diagnosing elevated BP as early as possible is important because of the increased subsequent risk of adult hypertension, left ventricular hypertrophy and metabolic syndrome.[8,32] The present study's findings show that the adoption of updated normative tables, as suggested by AAP 2017 (and implied by HC 2020), would increase the number of children and adolescents reclassified as having hypertension, most of whom are at higher cardiovascular risk, and thereby identify more individuals who would be eligible for treatment. Whether early identification of and intervention for these children and adolescents improve long-term cardiovascular health is unclear,[10] but it is a subject of current investigation.[33]

Strengths and limitations

This study has several strengths. To the authors' knowledge, this is the first study in Canada to compare national child and adolescent hypertension prevalence estimates based on NHBPEP 2004, AAP 2017 and HC 2020. This study also used data from the CHMS, a nationally representative, population-based survey used for BP and hypertension surveillance of the Canadian population. BP was measured objectively over six

cycles of the CHMS using the same automated device with a standardized technique. Height, weight and WC were each directly measured using systematic methodologies.

A key limitation of this study is that BP was measured using an automated oscillometric device. All three sets of guidelines recommend that auscultatory methods be used to measure the BP of children and adolescents. The BP normative tables used in each set of guidelines to classify children and adolescents as hypertensive were based on data collected using an auscultatory technique, a technique that may provide different BP values from measurements obtained using oscillometric devices.[8] Moreover, the magnitude and direction of the difference between the methods and the effect on hypertension prevalence are unclear.[29,34] Owing to limited sample sizes in the prehypertension or elevated BP, Stage 1 hypertension, and Stage 2 hypertension categories, particularly among adolescents aged 13 to 17, selected associations and patterns in reclassification could only be examined with all six cycles of data combined.

Conclusion

This study found that the prevalence of Stage 1 hypertension was higher among children and adolescents aged 6 to 17 under AAP 2017 and HC 2020 than under NHBPEP 2004 and higher among those aged 13 to 17 under AAP 2017 than under HC 2020 and NHBPEP 2004. Overall hypertension prevalence (Stage 1 and Stage 2 combined) was higher under AAP 2017 and HC 2020 than under NHBPEP 2004, and obesity was a major factor associated with being reclassified into a higher BP category. Understanding the impact of applying updated clinical guidelines may help inform population surveillance efforts to track hypertension prevalence among Canada's children and adolescents.

Appendix Table 1
Blood pressure classification according to NHBPEP 2004, AAP 2017 and HC 2020

	Blood pressure (BP) categories			
Guidelines, population	**Normal BP (SBP/DBP, mmHg)**	**Prehypertension (SBP/DBP, mmHg)**	**Stage 1 hypertension (SBP/DBP, mmHg)**	**Stage 2 hypertension (SBP/DBP, mmHg)**
NHBPEP 2004, ages 1 to 17	<90th percentile for age, sex and height	90th to <95th percentile or if BP exceeds 120/80 even if <90th up to <95th	95th percentile to (99th percentile plus 5 mmHg)	>99th percentile plus 5 mmHg
AAP 2017, ages 1 to 12	<90th percentile for age, sex and height	≥90th to <95th percentile or 120/80 mmHg to <95th (whichever is lower)	≥95th percentile to (<95th percentile plus 12 mmHg) or 130/80-139/89 mm Hg (whichever is lower)	≥95th percentile plus 12 mmHg or ≥140/90 mmHg (whichever is lower)
AAP 2017, ages 13 or older	<120/80 mmHg	120/<80 to 129/<80 mmHg	130/80 to 139/89 mmHg	≥140/≥ 90 mmHg
HC 2020, ages 1 to 17	…	…	≥95th percentile to (<95th percentile plus 12 mmHg)	≥95th percentile plus 12 mmHg

… not applicable

Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017; HC 2020 = *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* published by Hypertension Canada in 2020; SBP = systolic blood pressure; DPB = diastolic blood pressure; and mmHg = millimetres of mercury.

Sources: NHBPEP 2004 classification adapted from Table 5 in NHBPEP 2004. AAP 2017 classification adapted from Table 3 in AAP 2017. HC 2020 classification adapted from pages 615 and 616 in HC 2020. Percentiles for age, sex and height under NHBPEP 2004 are based on normative tables provided in NHBPEP 2004. Percentiles for age, sex and height under AAP 2017 and HC 2020 are based on normative tables published online by Dr. B. Rosner (available at https://sites.google.com/a/channing.harvard.edu/bernardrosner/pediatric-blood-press/childhood-blood-pressure).

Appendix Table 2
Sample size and weighted proportion distribution of children and youth across blood pressure categories and selected characteristics, 2007 to 2019

			95% Confidence interval	
	n	%	from	to
Total	**11,064**	**100.0**	**...**	**...**
NHBPEP 2004				
Normal	10,426	94.7	94.2	95.2
Prehypertension	307	2.7	2.3	3.2
Stage 1 hypertension	253	2.1	1.7	2.5
Stage 2 hypertension	78	0.5	0.4	0.8
AAP 2017				
Normal	10,356	94.0	93.3	94.7
Elevated BP	254	2.1	1.7	2.6
Stage 1 hypertension	372	3.3	2.9	3.8
Stage 2 hypertension	82	0.5	0.3	0.8
HC 2020				
Stage 1 hypertension	351	3.0	2.6	3.5
Stage 2 hypertension	78	0.5	0.3	0.8
Age group				
6 to 12	7,132	57.1	56.0	58.3
13 to 17	3,932	42.9	41.7	44.0
Sex				
Male	5,574	51.4	50.6	52.1
Female	5,490	48.6	47.9	49.4
Born in Canada				
Yes	9,769	86.8	84.4	88.9
No	1,294	13.2	11.1	15.6
Body mass index category				
Neither overweight nor obese[1]	7,416	67.5	65.6	69.3
Overweight	2,039	18.0	16.7	19.4
Obese	1,380	12.3	11.1	13.5
Central obesity category				
Not at risk of central obesity	8,860	80.1	78.2	81.9
At risk	1,177	10.6	9.6	11.8
Centrally obese	999	9.2	8.1	10.5
Height z-score				
Low	161	1.8	1.3	2.5
Low-middle	1,009	9.1	8.2	10.2
Middle	7,402	66.6	65.1	68.0
High-middle	2,002	18.2	16.9	19.6
High	490	4.3	3.8	4.9

...not applicable

[1] Excludes those whose measured body mass index (BMI) was less than or equal to two standard deviations below the mean BMI for age.

Notes: NHBPEP 2004 = *The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents* published by the National High Blood Pressure Education Program in 2004; AAP 2017 = *Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents* published by the American Academy of Pediatrics in 2017; HC 2020 = *Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children* published by Hypertension Canada in 2020; BP = blood pressure; and CI = confidence interval.

Source: Statistics Canada, Canadian Health Measures Survey, 2007 to 2009, 2009 to 2011, 2012 to 2013, 2014 to 2015, 2016 to 2017, 2018 to 2019, combined.

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