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Implications of the 2017 AAP Clinical Practice Guidelines for Management of Hypertension in Children and Adolescents: a Review

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Abstract

Purpose of Review To evaluate the impact of the 2017 American Academy of Pediatrics Clinical Practice Guideline (2017 AAP CPG) for Screening and Management of High Blood Pressure in Children and Adolescents.

Recent Findings The 2017 AAP CPG had several significant changes compared to the 2004 Fourth Report. This review will focus on the emerging evidence from the first studies to apply the 2017 AAP CPG and the simplified table it contains on the overall prevalence of HTN and on recognition among children and adolescents at a higher cardiovascular risk.

Summary Recent evidence suggests that use of the 2017 AAP CPG will result in an overall increase in prevalence of HTN, particularly in youth who are obese or who have other cardiovascular risk factors. The change in prevalence likely differs based on sex, age, and height. The ability for the 2017 AAP CPG to detect an association with hypertension and target organ damage requires further study. Continued study is required to assess long-term implications of the 2017 AAP CPG with the goal of a more meaningful HTN definition in the young.

Keywords Pediatric hypertension · Elevated blood pressure · Stage 1 hypertension · Stage 2 hypertension · Secondary hypertension · Prevalence of hypertension · Abnormal left ventricular geometry · 2017 AAP Clinical Practice Guideline for High Blood Pressure in Children and Adolescents

Introduction

Since the publication of the *2004 Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure (BP) in Children and Adolescents* (2004 Fourth Report) [1], mounting evidence has linked hypertension (HTN) in childhood and adolescents with intermediary markers of cardiovascular disease (CVD) and to increased risk of CVD in adulthood [2, 3]. Increasing evidence has shown that childhood and adolescent HTN tracks into adulthood. The rise in childhood HTN over the last several decades, likely associated with the childhood obesity epidemic, has significant implications for development of adult CVD. In 2017, the American Academy of Pediatrics Clinical Practice Guideline for Screening and Management of High BP in Children and Adolescents (2017 AAP CPG) [4••] was published to update the current guidelines based on a rigorous systematic review of evidence published since the 2004 Fourth Report. The 2017 AAP CPG also aimed to improve recognition of pediatric HTN by simplifying the diagnosis and evaluation of HTN in children and adolescents.

The 2017 AAP CPG had several notable changes from the 2004 Fourth Report. The most prominent changes included alterations in the categorization of high BP (HBP), including simplification of BP categorization for adolescents, revision of the normative pediatric BP values, and alignment with the updated American College of Cardiology (ACC)/American Heart Association (AHA) guideline for adult HTN [5]. The 2017 AAP CPG included an expanded role for the use of 24-h ambulatory BP monitoring (ABPM). The updated guideline also sought to aid recognition by including a simplified screening table.

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Given the significant changes in the 2017 AAP CPG, there is a need to evaluate its impact on the prevalence of pediatric HTN and on the ability to identify children and adolescents likely at increased risk for CVD. Further, the effect of the guidelines on ability to recognize pediatric HTN is critical. The goal of this review is to discuss the evidence based on the studies that have applied the 2017 AAP CPG to these questions.

Key Changes in the 2017 AAP CPG

Several fundamental changes in the 2017 AAP CPG deal with alterations to the classification of BP. To address one of the leading criticisms of the 2004 Fourth Report, the authors revised the normative tables for pediatric BP values by excluding overweight and obese children. This resulted in a reduction of 2–3 mmHg in BP values compared to those in the Fourth Report [6, 7]. Within the normative tables, stage 2 HTN for children < 13 years was redefined to BP values ≥ 95th percentile + 12 mmHg instead of the 99th + 5 mmHg. To provide consistency with the adult guidelines and ease transition from pediatric to adult providers, the 2017 AAP CPG applied the adult threshold of 130/80 to adolescents, both male and female, aged 13 years and above. The static threshold in adolescents also works to simplify diagnosis with hopes to improve recognition in this age category. In addition to revising the BP cutoffs, the term "elevated BP" has replaced "prehypertension" (preHTN). This change serves to be in better accordance with the adult guidelines, especially for adolescents in whom the same static adult threshold values are used to categorize BP (see Table 1 for a synopsis of the BP definition in the 2017 AAP CPG and a comparison with the 2004 Fourth Report and 2016 European Society of Hypertension Guidelines (ESHG)).

In addition to adopting a static threshold for adolescents, the 2017 AAP CPG has other notable changes aimed at helping to simplify and improve recognition of HBP. The CPG includes a new simplified screening table with blood pressure cutoffs at the 5th percentile for height for every age for males and females under 13 years. To aid diagnosis, the CPG provides an algorithm for providers focused on BP measurement and classification. There is emphasis on utilizing the alerts in the electronic health record as this has been shown to improve recognition [8].

The 2017 AAP CPG has decreased the extent of initial workup for HTN in those over 6 years of age. This serves both to simplify diagnosis and address the increasing epidemic of essential HTN. As per the 2017 AAP CPG, all children and adolescents should have blood and urine tests to rule out renal causes. The guidelines reserved other laboratory workups for those with additional risk factors. Renal ultrasound is only recommended universally for those under 6 years. The most notable change is the delay of the echocardiogram until the provider is considering antihypertensive treatment. Further, the 2017 AAP CPG adopted a cutoff for elevated left ventricular mass index (LVMI) of 50 g/$m^{2.7}$ instead of the 95th percentile.

Another important change in the 2017 AAP CPG is an increased role for ABPM. There was little mention of ABPM in the 2004 Fourth Report. In the last 14+ years, there has been an explosion of evidence demonstrating the utility and superiority of ABPM in diagnosis of BP over office BPs [9–12]. The 2017 AAP CPG has 7 key action statements involving the use of ABPM. Highlights of the most important recommendations regarding ABPM include:

- ABPM should be performed as confirmation for HTN and after 1 year of elevated office BP readings. Similarly, ABPM should be utilized if white coat hypertension (WCH) is suspected.
- ABPM is recommended for those with high-risk conditions with the rationale that these youth are at an increased risk for target organ damage (TOD) secondary to masked hypertension (MH) and other disruptions to circadian rhythm. Two key action statements specifically recommend ABPM for children and adolescents following repair of coarctation of the aorta and those with chronic kidney disease (CKD).
- ABPM should be performed using a standardized approach, interpreted with pediatric normative data and with monitors that have been validated in children and adolescents.
- ABPM for assessment of management especially when there is concern for poor BP control.

The 2017 AAP CPG recommends new, lower treatment targets. For those without additional risk factors, treatment should target BP < 90th percentile given recent evidence that TOD may appear at BP values below the 95th percentile. For those with CKD, regardless of whether or not there is proteinuria, the treatment goal is now < 50th percentile for MAP as based on the ABPM. Lifestyle modification with dietary changes and increased physical activity remains the primary step in treatment except for severe hypertension or presence of TOD. The 2017 AAP CPG clarified the choice of first-line antihypertensive medications as renin-angiotensin-aldosterone system (RAAS) blockers, long-acting calcium channel blockers, and thiazide diuretics. These are started if an adequate trial of lifestyle modifications has failed.

Table 1 Definition of hypertension (HTN) based on the 2017 AAP CPG, 2016 ESH Guidelines, and the 2004 Fourth Report

	2017 AAP CPG		2016 ESH Guidelines		2004 Fourth Report
	< 13 years	≥ 13 years	< 16 years	≥ 16 years	
Normal BP	< 90th percentile	< 120/< 80	< 90th percentile	< 130/85	< 90th percentile
Elevated BP*	≥ 90th to < 95th percentile or 120–129/< 80	120–129/< 80	≥ 90th to < 95th percentile	130–139/85–89	≥ 90th to < 95th percentile or > 120/80
Stage 1 HTN	≥ 95th to < 95th percentile + 12 mmHg or 130/80 to 139/89	130–139/80–89	≥ 95th to < 99th percentile + 5 mmHg	140–159/90–99	≥ 95th to < 99th percentile + 5 mmHg
Stage 2 HTN	≥ 95th percentile + 12 mmHg or ≥ 140/90	≥ 140/90	≥ 99th percentile + 5 mmHg	160–179/100–109	≥ 99th percentile + 5 mmHg

*Referred to as preHTN in the 2004 Fourth Report

Abbreviations: *AAP*, American Academy of Pediatrics; *BP*, blood pressure; *CPG*, clinical practice guideline; *ESH*, European Society of Hypertension; *HTN*, hypertension

Expected Effect on Prevalence of HTN in Youth

Roughly simultaneous to the publication of the 2017 AAP CPG, the ACC and AHA published updated adult BP guidelines based on the highest quality current evidence regarding the impact of HTN on CVD outcomes [5]. Mutner et al. sought to determine the potential impact on prevalence of HTN and antihypertensive medication use of the 2017 ACC/AHA CPG as compared to the "Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High BP" (JNC-7) [13]. Utilizing data from 2011 to 2014 National Health and Nutrition Examination Survey (NHANES), Mutner and colleagues found a substantial increase in the overall prevalence of HTN to 45.6% (95% confidence interval (CI), 43.6–47.6%) of US adults based on the 2017 ACC/AHA CPG from 31.9% (95% CI, 30.1–33.7%) based on the JNC-7 guideline. The investigators found this increase within all subgroups based on age, sex, CVD risk, and race-ethnicity. They found a small increase in recommendation for antihypertensive medication to 36.2% (95% CI, 34.2–38.2%) from 34.3% (95% CI, 32.5–36.2%). Not surprisingly, they also found that those newly recommended to be treated with antihypertensive medication by the 2017 ACC/AHA CPG were more likely to have an increased CVD risk. Conversely, those classified as hypertensive by the 2017 ACC/AHA guideline but not the JNC-7 tended to be younger and with less CVD risk.

Experts predict that the 2017 AAP CPG will demonstrate a similar overall increase in prevalence of HTN [6, 14]. When considering both the new normative BP tables and the static BP thresholds for adolescents, some predict that the impact will vary based on age, sex, and height. For example, younger and shorter children will not see an increase in prevalence of stage 2 HTN as the new CPG definition gives a higher stage 2 threshold [14]. Others are wary that HTN may be underrecognized in younger adolescent females given that the prior 95th percentile exceeds the static thresholds only in tall females for the younger adolescents [15].

Recent Studies: First Applications of the AAP CPG

There are now five key studies comparing the application of the 2017 AAP CPG with that of the 2004 Fourth Report (Table 2). Sharma et al. was the first to publish results of their study aimed at assessing the impact of the 2017 AAP CPG both on the overall prevalence of HTN and the prevalence of upward reclassification of elevated BPs with secondary analyses examining other risk factors [16•]. This study utilized a cross-sectional design applying both sets of guidelines to BP measurements from NHANES data to 15,647 generally healthy children aged 5 to 18 years between January 1, 1999, and December 31, 2014. For analysis, the investigators matched each child who underwent upward classification by sex, age, and height with children who had a normal BP. Authors used age- and sex-specific *z* scores for weight to compare anthropometric and laboratory risk factors. Applying the 2017 AAP CPG, the estimated (weighted) population prevalence of HBP (elevated BP/preHTN and HTN) increased from 11.8% (95%CI, 11.1–13.0%) to 14.2% (95%CI, 13.4–15.0%) as compared to the 2004 Fourth Report with sample prevalence increasing from 12.8% (95%CI, 12.3–13.0%) to 15.0% (95%CI, 14.4–16.0%). For children under the age of 13 years, the mean SBP percentile was higher with the 2017 AAP CPG. Overall, the investigators found 5.8% or 950 of the 15,584 were either reclassified as newly hypertensive or to an increased stage of HTN. Of those who underwent upward reclassification, nearly half (470) were reclassified from preHTN/elevated BP to stage 1, 40.1% (381) were reclassified from normotensive to elevated

Table 2 Key findings from the first studies to apply the 2017 AAP CPG

Study(ref no.)	Study design/population	Key findings comparing the AAP CPG to the Fourth Report
Sharma et al. [16•]	Cross-sectional, NHANES	• ↑ in HBP (11.8 to 14.2%) with AAP CPG • ↑ likelihood of greater CVD risk in those upward reclassified
Khoury et al. [17•]	Cross-sectional, population with increased CVD risk	• ↑ in HTN among a high-risk population (8 to 13%) • ↑adolescent/obese participants upward reclassified • ↑sensitivity in identification of TOD in HTN patients
Dong et al. [18•]	Cross-sectional, Chinese youth	• ↑ in HBP (10.8 to 16.7% in children, 6.3 to 7.9% adolescents) • Greatest ↑ in males, ages 9–11 years, obese, tall; no change for adolescent females, children of short stature
Al Kibria et al. [20•]	Cross-sectional, NHANES, 2 periods	• Modest ↑ in HBP/HTN, greater for the earlier time period • ↑ proportion of obese, male participants
Bell et al. [21•]	Cohort, Houston school-based screening program	• ↑ in HBP (14.8 to 16.3%) but prevalence of HTN slightly ↓ (2.7 to 2.3%) • Over-representation of ages 11 to 15 years
		Key findings comparing the AAP CPG to the ESHG
Di Bonito et al. [26•]	Cross-sectional, from CARITALY study	• ↑ of 4.1% in HBP • ↑ proportion of overweight and obese participants • ↑ sensitivity for identification of ALVG with 95th percentile cutoffs but no association with adult cut-off

Abbreviations: *HBP*, high blood pressure; *AAP CPG*, 2017 AAP Clinical Practice Guidelines; *ALVG*, abnormal left ventricular geometry; *BMI*, body mass index; *CVD*, cardiovascular disease; *Fourth Report*, 2004 Fourth Report; *HTN*, hypertension; *NHANES*, National Health and Nutrition Examination Survey; *TOD*, target organ damage

BP, 1.4% (13) from normotensive to stage 1, and 5.7% (54) from stage 1 to stage 2. The study noted 40 who were reclassified downward to normotensive from preHTN/elevated BP and 33 from stage 1 to elevated BP. Sharma et al. demonstrated that those who were reclassified upward were statistically more likely to be male, have higher BMI and other markers of adiposity, and were taller. Further, those reclassified upward did have statistically significant worsening in most lab markers of metabolic syndrome including hemoglobin A1C, LDL cholesterol, and triglycerides. Of those who experienced an upward reclassification, 67.5% had an additional risk factor(s) compared to only 35% of normotensive subjects.

Khoury et al. also compared the prevalence and classification of HTN between the 2017 AAP CPG and the 2004 Fourth Report, but in a small population of high-risk children and adolescents [17•]. The investigators utilized standardized anthropometric measurements and laboratory data from a larger study of children ages 10–18 years who were either obese, obese with type 2 diabetes mellitus (DM), or lean (comparison group). In addition, the study measured target organ damage (TOD) with carotid intimal thickness (cIMT), pulse wave velocity (pwv), LVMI, and diastolic function.

This study showed that the application of the 2017 AAP CPG resulted in a statistically significant increase in prevalence of HTN in this high-risk group as compared to the 2004 Fourth Report with 13% (10% stage 1 and 3% stage 2) vs. 8% (6% as stage 1 and 2% as stage 2), respectively. The greatest increase resulted from those being upward reclassified from preHTN as defined in the 2004 Fourth Report to stage 1. Those who underwent upward reclassification were more likely to be adolescents and obese. They also tended to be male (68%) but this was not statistically significant (p value 0.06). Despite the increase in prevalence, the association with TOD was similar and not weakened with the 2017 AAP CPG as compared to the 2004 Fourth Report. Further, the 2017 AAP CPG showed improved sensitivity of TOD identification in hypertensive patients in those of increased CVD risk. Of note, the study derived normal values for the markers of TOD from the lean-body mass participants, and the cutoff for LVMI was 38.6 g/m$^{2.7}$. The discrepancy in cutoff for LVMI and the lack of normative cutoffs for other measures of TOD illustrate the limited evidence of cut points in pediatrics and requirement for further long-term studies. The use of a high-risk population of youth for CVD is both a strength as it mirrors many subspecialty HTN clinics and a limitation for overall generalizability.

Dong et al. sought to identify the prevalence of HTN in the 2017 AAP CPG compared to the 2004 Fourth Report in a representative sample of Chinese youth aged 6 to 17 years through a national multicenter school-based intervention program conducted in September of 2013 [18•]. This study demonstrated an overall increase in prevalence of HBP with 16.7% of children ages 6 to 12 years and 7.9% of adolescents classified as HBP in the 2017 AAP CPG as compared to only 10.8% of children and 6.3% of adolescents with the 2004 Fourth Report. Boys and those of taller stature saw a greater increase in upward classification of BP. The groups that did

not see a statistically significant increase in prevalence included adolescent females, children of short stature, and adolescents with a low BMI. With the 2017 AAP CPG, females saw a decrease at age 13 years, stabilized at age 14 years, and then a gradual increase in classification of HTN from ages 15 to 17 years. The 9- to 11-year-olds had the greatest increase in prevalence of HTN between the two definitions with only 4.2% classified as hypertensive in the 2004 Fourth Report and 11.2% classified as hypertensive in the 2017 AAP CPG. This was second to the exclusion of overweight and obese children from the normative tables, which resulted in the greatest decrease in BP cutoffs within this age group. This change is intuitive as the prevalence of overweight and obesity is greatest at these ages. Overall, HTN was associated with increasing BMI with both sets of definitions. Except for girls ages 13 to 17 years, the difference in prevalence became larger between the two guidelines with increasing BMI. In agreement with prior studies [19], this study demonstrates strong and consistent associations between obesity, family history, early life factors, and behavioral factors.

Al Kibria et al. also studied the estimated change in prevalence and trends following application of the 2017 AAP CPG as compared to the 2004 Fourth Report [20•]. They specifically sought to expand on the study performed by Sharma et al. by looking at baseline trends in HTN over that 16-year time period. Specifically, the investigators utilized NHANES data for 8- to 17-year-olds over two time periods, 2005–2008 and 2012–2016. They chose this age range based on the objectives in CDC's Healthy People 2020 (HP 2020) campaign. This study defined HTN as stage 1 or stage 2 and HBP as both HTN and either elevated BP by the 2017 AAP CPG or preHTN as by the 2004 Fourth Report. In total, there were 3633 children in the first time period and 3471 in the second time period. The study found that the prevalence of HBP and HTN was lower in the second time period with application of either guideline. Per the 2017 AAP CPG, 5.7% (95%CI, 4.6–7.1%) had HTN and 15.2% (95%CI, 12.8–17.9%) had HBP during 2005–2008 compared to 3.5% (95%CI, 2.7–4.5%) with HTN and 10.6% (95%CI 9.3–12.0%) with HBP during the 2013–2016. Use of the 2017 AAP CPG classified more children as having HTN than the 2004 Fourth Report during the first time period of 2005–2008 with an increase of 2.5% (95%CI 2.0–3.1) in prevalence of HTN and 1.7% (95%CI, 1.2–2.2) for prevalence of HBP. While citing a similar increase during the later time period, both confidence intervals for the increase in prevalence between the guidelines overlapped 1.0 with an increase of 1.5% (95%CI, 0.9–2.0) for HTN and 1.11% (0.6 to 1.6) for HBP.

These investigators reported a higher proportion of overweight or obese children classified as hypertensive in the 2017 AAP CPG as compared to the 2004 Fourth Report. There was a greater increase or difference in prevalence of HTN and HBP in boys as compared to girls between the two guidelines. The prevalence of HTN was the highest among children aged 8 to 12 years per the 2017 AAP CPG in 2013–2016 estimated at 5.5% with 95%CI 4.1–7.3%. These data suggest that an additional 18.9% of children could require evaluation for HTN based on their BP measurements. The increases were more significant in the HTN group than in the HBP group, indicating there was likely more upward reclassification from the prior designation of preHTN to stage 1 or stage 2 than upward reclassification from normotensive to elevated BP or HTN. This study did not analyze data in terms of both age and sex categories together based on the two age categories (< 13 years and ≥ 13–17 years) in the 2017 AAP CPG. This study is notable in that it demonstrates a recent, modest decrease in HTN prevalence. The increase in HTN and HBP between the two guidelines was only significant for the first time period.

The final study examining prevalence is from Bell and colleagues who applied the 2017 AAP CPG to a cohort of children from a school-based screening program [21•]. This cohort included 22,224 students aged 10 to 17 years (89% were 11–15 years old) screened as part of the Houston Pediatric HTN Program at the University of Texas McGovern Medical School. Children who had a BP ≥ 90th percentile for age or ≥ 120/80 at the initial screening were screened on two additional occasions to confirm the diagnosis of HTN. The prevalence of HBP increased to 16.3% with the 2017 AAP CPG as compared to 14.8% from the 2004 Fourth Report. The overall prevalence of HTN (stage 1 or stage 2) was slightly less at 2.3% in the 2017 AAP CPG as compared to 2.7% in 2004 Fourth report. The increase in elevated BP resulted from an upward reclassification of children under 13 from normotensive, and a downward reclassification of those ≥ 13 years from stage 1 to elevated BP. Children under 13 were more likely in general to have upward reclassification with less being classified as normotensive (74.1% in the 2017 AAP CPG as compared to 75.5% in the Fourth Report). Adolescents showed an increased likelihood for reclassification downward, and slightly more were classified as normotensive with 68.8% as normotensive per the 2017 AAP CPG as compared to 67.8% in the Fourth Report. Beyond age, there was also differential classification between the two guidelines based on sex and height. Younger shorter boys were more likely to be classified as being hypertensive whereas older shorter boys were less likely to be classified as being hypertensive with the 2017 AAP CPG. Females had similar but more blunted patterns.

Strengths and Limitations

The above five studies are extremely helpful in elucidating the likely impact of the 2017 AAP CPG. All five studies are limited by their inability to diagnose WCH secondary to lack of ABPM or other out-of-office BP data. The four cross-

sectional studies are all limited secondary to measurements being conducted at one encounter, which will overestimate the prevalence of HTN. Studies by Sharma, Khoury, and Dong are all cross-sectional and show similar increases in overall prevalence of HTN with the 2017 AAP CPG. Al Kibria et al. also performed a cross-sectional study which shows a smaller and less significant increase in prevalence, especially in the later time period of 2012–2016 which may reflect a recent stabilization in the overall prevalence of HTN with improvement in treatment and recognition of HTN in obese children. The lower overall prevalence of HTN in the 2017 AAP CPG noted by Bell et al. is likely secondary to over-representation of ages shown to be less impacted by the 2017 CPG AAP in the prior studies, particularly young adolescents. All five studies indicate the largest discrepancies between the two guidelines in older children are within the age range of 8 to 12 years, with some variability depending on the cut points used. All studies also indicate that the 2017 AAP CPG better classifies those who are obese as being hypertensive. Both findings are likely directly related to the new normative tables which exclude overweight and obese children.

In accordance with some author's fears, the studies by Sharma, Dong, Khoury, and Bell all show a greater tendency for males to be reclassified as being hypertensive over females, especially in adolescents. This likely reflects the application of the static adult threshold on females starting at age 13 years. These same four studies also show a trend for taller boys under 13 years to be more likely to be reclassified as hypertensive than shorter boys. From the data presented, no trends on the impact on stage 2 HTN by the 2017 AAP CPG were clearly identified. Studies published by Sharma et al. and Khoury et al. clearly indicate that those reclassified by the 2017 AAP CPG are more likely to have higher CVD risk profiles by either laboratory analysis or TOD assessment. Thus, from these early studies, there is a suggestion that the 2017 AAP CPG is likely better at estimating the cardiovascular risk given that children and adolescents who reclassified either as newly hypertensive or at an increased stage were more likely to have increased CVD risk. This improved classification of youth at risk arguably can justify the increased burden on healthcare providers and families secondary to the likely increased prevalence.

Evaluation of the New Screening Table

One of the key aims of the 2017 AAP CPG was to simplify the diagnosis and recognition of HTN in children and adolescents. The simplified screening table is a key component to help improve recognition. Yang et al. looked at the overall sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) of the simplified table using NHANES data [22]. They found that the new screening table had optimal sensitivity and NPV of 99.9% and 100.0%, respectively, but a lower specificity of 84.4%, which resulted in a low PPV of 46.9%. Results were similar for different ages, sex, BP level, and race/ethnicity. The investigators compared six additional simplified tables using cutoffs of 10th, 25th, 50th, 75th, 90th, and 95th height percentiles for age and sex for 5–12-year-olds or cutoff of ≥ 120/80. They found that sensitivity decreased markedly from 99.9 to 75.7% with the expected increase in specificity from 84.4 to 99.3%. PPV also had an expected significant increase from 46.0 to 94% at the 95th percentile, but there was only a small decrease in NPV from 100% to 96.7% at the 95th height percentile. The authors argued that while this may be appropriate in the clinic setting, using a simplified table based on a higher height percentile such as the 75th may be more useful in resource limited screening settings like school programs. Their conclusions have been criticized by the authors of the 2017 AAP CPG, who argue that to maintain the integrity of the table as a screening tool, it requires the highest sensitivity possible [23]. Increasing the height percentile may also differentially decrease sensitivity in those at highest risk for secondary hypertension as those with CKD or genetic syndromes are often shorter than their peers.

Role of ABPM

The expanded role of ABPM in the 2017 AAP CPG has drawn a great deal of attention and some criticism in the literature. There were several motivations for the increased focus on ABPM [24]. First, it was felt to be an important and cost-effective measure in order to avoid unnecessary evaluation and treatment in those with WCH. Further, the expanded use was felt to be consistent with recent adult consensus guidelines including the 2015 United States Preventative Services Task Force and NICE (National Institute for Health and Care Excellence) guidelines.

Macumber recently wrote a review further supporting the importance of ABPM in the diagnosis of pediatric HTN [11]. The review highlighted several of the recommendations from the 2017 AAP CPG regarding ABPM use and detailed the growing evidence for use of ABPM in pediatrics. Macumber discussed the value of ABPM for evaluation of both WCH and MH in particular populations such as those with CKD, type 1 diabetes, renal transplant recipients, and coarctation. At the same time, the need for improved normative data and outcomes research utilizing ABPM was stressed. In another recent review, Dionne likewise highlighted the increasing evidence of the utility over office BPs in the diagnosis of HTN including in those at high risk as well as the ability to detect WCH, MH, NH, and decreased nocturnal dipping [6]. She did, however, critique the extensive reliance on ABPM in the 2017 AAP CPG citing the lack of broad availability,

barriers to increased availability including poor reimbursement, and the need for improved normative values used to interpret pediatric ABPMs. Brady et al. echoed this critique feeling that the limited availability and reimbursement for the test render it unsuitable for such a strong recommendation [15]. In a review by Samuels and Samuel, they argue that the increased emphasis on evaluation with ABPM is supported by strong evidence and the overall key provisions of the 2017 AAP CPG are focused on simplifying and easing recognition and diagnosis of pediatric HTN [12].

Differences in the New CPG as Compared to the European Guidelines

At this point, much of this review has focused on the impact of the guidelines as compared to the 2004 Fourth Report. However, the 2016 ESHG has also recently been published. Both Lurbe et al. [25] and Brady et al. [15] have written reviews discussing the major changes between the two guidelines, the most significant of which are differences in the categorization of BP between the two guidelines (see in Table 1). Other notable differences between the 2016 ESHG and 2017 AAP CPG include:

- Retention of the prior normative tables without the exclusion for overweight and obese children in the 2016 ESHG.
- Application of the European adult BP thresholds (≥ 140/90) at age 16 years instead of the ACC thresholds (≥ 130/80) at age 13 years.
- ESHG recommends ABPM prior to initiation of antihypertensive medication.
- ESHG continues to recommend extensive evaluation at diagnosis, including an echocardiogram, as compared to a limited evaluation at diagnosis and delay of echocardiogram until prior to treatment with antihypertensive medication in the 2017 AAP CPG.
- ESHG uses the 95th percentile for threshold of elevated LVMI vs. the adult threshold of 51 g/m$^{2.7}$ in the 2017 AAP CPG.

In addition to these two reviews, Di Bonito and colleagues recently conducted a cross-sectional study comparing the impact of the 2016 ESHG and the 2017 AAP CPG on the prevalence of HTN and on the ability to classify abnormal left ventricular geometry (ALVG) in overweight/obese children and adolescents [26•]. The study population comprised 6137 overweight/obese children and adolescents including 437 with an echocardiographic assessment from the "CARdiometabolic risk factors in overweight and obese children in ITALY" (CARITALY) study designed to assess the prevalence of cardiometabolic risk factors in overweight/obese youth referred for evaluation to secondary and tertiary centers. The investigators defined HTN and ALVG as per guideline. This study found an increase in prevalence of children and adolescents at high risk of HTN (having a hypertensive measurement at the study visit) was 4.1% greater (34.8% vs. 30.7%) using the 2017 AAP CPG as compared to the 2016 ESH guideline. The increase was largest in overweight and obese adolescents. Using the juvenile cutoffs for ALVG, youth at a high risk of HTN by 2016 ESHG had an odds ratio of 3.03 (95%CI, 1.31–7.05) for left ventricular concentric remodeling (LVcr) and 2.53 (95% CI, 1.43–4.47) for concentric left ventricular hypertrophy (cLVH) as compared with youth with normal LVG. The odds ratio was slightly larger for those with a hypertensive measurement as per the 2017 AAP CPG with an odds ratio for LVcr of 3.28 (95%CI, 1.45–7.41; $P < 0.001$) and 3.02 (95%CI, 1.73–5.27; $P < 0.001$) for cLVH. Using the adult cutoffs, no significant difference in ALVG was found with both guidelines. This study argues that in a population of overweight and obese children, the 2017 AAP CPG identifies more as hypertensive across all age and sex categories, which can aid in recognizing the cardiometabolic risk in this high-risk population. However, since the 2017 AAP CPG applies the adult cutoffs for ALVG, the study argues that the 2017 AAP CPG is unable to identify the expected association between ALVG and HTN. The authors argue that correctly classifying the cardiometabolic risk may allow treatment that will help prevent CV morbidity in adulthood given that there is some evidence that ALVG is reversible in pediatrics [27].

Conclusions

After a relatively short time since publication of the 2017 AAP CPG, we have already benefited from several studies addressing the impact of the new guidelines. While cross-sectional studies do have their limitations [7], especially with regard to diagnosis of HTN (which typically requires multiple encounters), the trends elucidated by the studies discussed herein are insightful. Initial evidence, as reviewed in this paper, does suggest an increase in prevalence of HTN. The magnitude of this increase is variable. There appears adequate agreement among the studies that those with obesity and other CVD risk factors are better classified as hypertensive in the 2017 AAP CPG as compared to both the 2004 Fourth Report and the 2016 ESHG. With regard to the 2016 ESHG, Di Bonito and colleagues raise concern about the ability of the adult cutoff for elevated LVMI to detect the previously demonstrated association with pediatric HTN and elevated LVMI. The available literature also highlights that the impact of the 2017 AAP CPG does vary by sex and age as well as potentially by height.

While the likely increased prevalence of HTN in the 2017 AAP CPG may increase the burden on the healthcare community and families, it is well justified if we are better at

identifying those at high risk for CVD and the morbidity and mortality from CVD. Better recognition of these high-risk youth can allow more intensified evaluation and intervention, as well as focused follow-up, all of which may serve to decrease long-term CVD morbidity and mortality.

Continued research is required to determine the impact of the new normative tables in the 2017 AAP CPG. This will allow continued targeting of these cutoffs given the inherent challenge of the rarity for CVD outcomes in pediatrics. Likewise, further research is needed to delineate appropriate cutoffs for TOD in pediatrics. This will allow for long-term research to measure the impact of management as recommended in the 2017 AAP CPG on the intermediary CVD outcomes given the challenge to directly link to CVD outcomes such as myocardial infarct and stroke.

Finally, research is needed to assess the impact of the 2017 AAP CPG on the recognition of childhood and adolescent HBP. Yang et al. illustrate that the simplified screening tool has nearly 100% sensitivity as intended but this results in a low PPV requiring additional verification. Regardless, it does appear that the 2017 AAP CPG is increasing awareness of childhood and adolescent HTN, which should be the first step at improved recognition.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. National High Blood Pressure Education Program Working Group. Fourth Report On The Diagnosis, Evaluation, And Treatment Of High Blood Pressure In Children And Adolescents. Pediatrics [Internet]. 2004;114:555–76. Available from: http://residenciapediatrica.com.br/detalhes/316/armazenamento-de-sangue-de-cordao–recomedacoes-da-academia-americana-de-pediatria.
2. de Simone G, Daniels SR, Devereux RB, Meyer RA, Roman MJ, de Divitiis O, et al. Left ventricular mass and body size in normotensive children and adults: assessment of allometric relations and impact of overweight. J Am Coll Cardiol. Elsevier Masson SAS. 1992;20:1251–60. https://doi.org/10.1016/0735-1097(92)90385-Z.
3. Shah AS, Khoury PR, Dolan LM, Ippisch HM, Urbina EM, Daniels SR, et al. The effects of obesity and type 2 diabetes mellitus on cardiac structure and function in adolescents and young adults. Diabetologia. 2011;54:722–30.
4. •• Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Daniels SR, et al. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. Pediatrics. 2017;140:e20171904. https://doi.org/10.1542/peds.2017-1904 **The publication of the 2017 AAP CPG**.
5. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, 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: executive summary: a report of the American College of Cardiology/American Heart Association Task F. Circulation. 2018.
6. Dionne J. Updated guideline may improve the recognition and diagnosis of hypertension in children and adolescents; review of the 2017 AAP blood pressure clinical practice guideline. Curr Hypertens Rep. 2017;19.
7. Daniels SR. What is the prevalence of childhood hypertension? It depends on the definition. JAMA Pediatr. 2018;172:519–20.
8. Kharbanda EO, Asche SE, Sinaiko AR, Ekstrom HL, Nordin JD, Sherwood NE, et al. Clinical decision support for recognition and management of hypertension: a randomized trial. Pediatrics. 2018;141:e20172954. https://doi.org/10.1542/peds.2017-2954.
9. Flynn JT, Daniels SR, Hayman LL, Maahs DM, Mccrindle BW, Mitsnefes M, et al. Update : ambulatory blood pressure monitoring in children and adolescents. Hypertension. 2014;63:1116–35.
10. Sorof JM, Cardwell G, Franco K, Portman RJ. Ambulatory blood pressure and left ventricular mass index in hypertensive children. Hypertension. 2002;39:903–8.
11. Macumber I. Ambulatory blood pressure monitoring in children and adolescents: a review of recent literature and new guidelines. Curr Hypertens Rep. 2017;19:96.
12. Samuels J, Samuel J. New guidelines for hypertension in children and adolescents. J Clin Hypertens. 2018:1–3.
13. Muntner P, Carey RM, Gidding S, Jones DW, Taler SJ, Wright JT, et al. Potential U.S. population impact of the 2017 American College of Cardiology/American Heart Association high blood pressure guideline. J Am Coll Cardiol. 2017;71:109–18 Available from: http://linkinghub.elsevier.com/retrieve/pii/S0735109717414744.
14. Miyashita Y, Hanevold C. Evaluation and management of stage 2 hypertension in pediatric patients. Curr Hypertens Rep. 2018;20:73.
15. Brady TM, Stefani-Glücksberg A, Simonetti GD. Management of high blood pressure in children: similarities and differences between US and European guidelines. Pediatr Nephrol. 2018.
16. • 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;172:557–65 **Cross-sectional study using NHANES data to look at impact of the 2017 AAP CPG as compared to Fourth Report on prevalence of HBP and association with CVD risk factors in children and adolescents**.
17. • Khoury M, Khoury PR, Dolan LM, Kimball TR, Urbina EM. Clinical implications of the revised AAP pediatric hypertension guidelines. Pediatrics. 2018;142 **Cross-sectional study evaluating the impact of the 2017 AAP CPG on prevalence of HTN and on recognition of HTN in high-risk CVD patients among a high-risk population**.
18. • 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. 2018;36:000–000 **Cross-sectional study on Chinese youth**

investigating the change in prevalence and differential classification of children and adolescents with the 2017 AAP CPG.

19. Gupta-Malhotra M, Shete S, Barratt MS, Milewicz D, Hashmi SS. Epidemiology of childhood onset essential hypertension. J Hum Hypertens. Springer US. 2018;32:808–13. https://doi.org/10.1038/s41371-018-0110-x.
20.• 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 Available from: http://www.ncbi.nlm.nih.gov/pubmed/30702999%0A, http://www.cdc.gov/pcd/issues/2019/18_0528.htm. **Cross-sectional study looking at the impact of the 2017 AAP CPG on prevalence of HTN during two time periods with NHANES**.
21.• Bell CS, Samuel JP, Samuels JA. Prevalence of hypertension in children. Hypertension. 2019;73:148–52. https://doi.org/10.1161/HYPERTENSIONAHA.118.11673 **Cohort study investigating the change in prevalence of HTN with the 2017 AAP CPG in a school-based screening program in Houston**.
22. Yang L, Hou Y, Zhao M, Bovet P, Xi B. Simplified blood pressure tables based on different height percentiles for screening elevated blood pressure in children. J Hypertens. 2018;37:292–6.
23. Flynn JT, Kaelber DC, Baker-Smith CM. The simplified table in the 2017 American Academy of Pediatrics childhood hypertension guideline performs exactly as intended. J Hypertens. 2018;36:2478–80.
24. Flynn JT, Falkner BE. New clinical practice guideline for the management of high blood pressure in children and adolescents. Hypertension. 2017;70:6883–686. https://doi.org/10.1161/HYPERTENSIONAHA.117.10050.
25. Lurbe E, Litwin M, Pall D, Seeman T, Stabouli S, Webb NJA, et al. Insights and implications of new blood pressure guidelines in children and adolescents. J Hypertens. 2018;36:1456–9.
26.• Di Bonito P, Valerio G, Pacifico L, Chiesa C, Invitti C, Morandi A, et al. Impact of the 2017 blood pressure guidelines by the American Academy of Pediatrics in overweight/obese youth. J Hypertens. 2018;36:000–000 Available from: http://insights.ovid.com/crossref?an=00004872-900000000-97330. **Cross-sectional study evaluating the impact of the 2017 AAP CPG on prevalence of HTN and also classification of those with HTN and ALVG in the 2017 AAP CPG as compared to the 2016 ESHG**.
27. Litwin M, Niemirska A, Joanna Ś, Wierzbicka A, Janas R, Wawer ZT, et al. Regression of target organ damage in children and adolescents with primary hypertension. Pediatr Nephrol. 2010;25:2489–99.