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Review Article

Pediatric hypertension: Current definition and knowledge gaps

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A B S T R A C T

Elevated blood pressure (BP) and hypertension are common in children and adolescents, significantly increasing the risk of cardiovascular disease (CVD) in adulthood. Accurately assessing the prevalence and significance of pediatric hypertension requires a clear definition. The use of age-, sex-, and height-dependent percentiles to define pediatric hypertension began in 1977. Since then, several national and international clinical practice guidelines have refined its classification, diagnosis, and management, with notable contributions from The Fourth Report in 2004, the European Society of Hypertension (ESH) in 2016, and the American Academy of Pediatrics (AAP) in 2017. The 2017 AAP guideline redefined pediatric hypertension, increasing the number of children classified with elevated BP or hypertension. Despite these advancements, a universal diagnostic criterion for pediatric hypertension is still lacking. This review aims to summarize recent research on pediatric hypertension, focusing on evolving definitions, persistent knowledge gaps, and future directions. Addressing pediatric hypertension early with a lifespan approach is essential to reducing the global prevalence of hypertension and its associated CVD burden. The need for continued study and innovative strategies is underscored by research gaps in the prevention, detection, classification, and treatment of pediatric hypertension.

1. Introduction

Hypertension affects approximately one-third of global population and it is a significant contributor to cardiovascular (CV) morbidity and mortality [1]. Since hypertension can originate early in life, addressing it during childhood and adolescence is crucial [2,3]. Although not all children with elevated blood pressure (BP) go on to develop hypertension as adults [4], elevated BP in childhood is a recognized risk factor for CV events later in life [5].

The global prevalence of pediatric hypertension has risen from 1.3 % in the 1990s to 6.0 % in the 2010s, with a pooled prevalence of 4 % [6]. Additionally, modifiable cardiovascular disease (CVD) risk factors commonly seen in adults, such as obesity and dyslipidemia, are increasingly prevalent among youth. Despite this rising trend, hypertension in children and adolescents remains under-recognized and under-diagnosed in clinical practice [7].

Given that hypertension-attributable CVD remains a leading cause of death in adults, bridging the knowledge gaps surrounding pediatric hypertension is critically important. Addressing these gaps will help improve clinical practices as patients transition across the life course, ultimately reducing long-term CV risks on a global scale.

1.1. Definition of pediatric hypertension

The prevalence and significance of pediatric hypertension cannot be accurately assessed without a clear definition. Efforts to standardize definitions and establish guidelines for its diagnosis and treatment began in 1977 [8]. Over time, several iterations of pediatric hypertension guidelines have been developed, with one of the most widely used being the Fourth Report from the National High Blood Pressure Education Program in 2004 [9].

The Fourth Report defines hypertension based on percentiles for age, sex, and height. Hypertension is defined as systolic or diastolic BP $\geq$ 95th percentile, while prehypertension is between the 90th and <95th percentiles. Stage 1 hypertension is BP from the 95th to 99th percentile +5 mmHg, and stage 2 hypertension exceeds the 99th percentile +5 mmHg [9]. As a result of variability in BP measurements, BP levels $\geq$95th percentile must be confirmed on three separate visits to establish a diagnosis. To simplify the process, a revised table was created, reducing the number of values from 476 to 64, making it easier to identify children and adolescents who may require further evaluation [10]. However, this approach did not significantly simplify the criteria for pediatric hypertension, and as a result it was not widely adopted in clinical practice.

To improve recognition of pediatric hypertension and align with adult guidelines, several national and international clinical practice

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guidelines have refined its classification, diagnosis, and management (Table 1) [11–15]. The European Society of Hypertension (ESH) [11], the American Academy of Pediatrics (AAP) [12], and Hypertension Canada (HC) [15] define hypertension as repeated BP readings ≥95th percentile for children but they differ on static thresholds for adolescents: ESH uses 140/90 mmHg from age 16, AAP uses 130/80 mmHg from age 13, and HC uses 130/85 mmHg for ages 12–17 and 120/80 mmHg for ages 6–11. Table 2 presents a comparison of diagnostic criteria and BP categorization in children and adolescents across the Fourth Report, ESH and AAP guidelines.

In 2016, ESH introduced a fixed threshold of 140/90 mmHg for diagnosing hypertension from age 16, regardless of gender or height [11]. This reclassification shifted many 16- and 17-year-old boys with SBP ≥95th percentile from "hypertensive" to "high-normal BP." In the 2017 AAP guidelines, BP classification in adolescents was simplified to threshold values consistent with adult guidelines. Specifically, a BP of 130/80 mm Hg was set as the threshold for hypertension starting at age 13 [12].

Table 1 outlines the key differences between the ESH and AAP guidelines, especially in reference nomograms and age cut-offs for BP thresholds. Before 2017, American and European guidelines used nomograms based on a reference population including children of all weight classes, but the 2017 AAP guidelines excluded overweight and obese children due to the strong link between hypertension and excess weight. Defining the reference population is critical, as the AAP's lower thresholds lead to an increase in hypertension prevalence, while the higher thresholds in the Fourth Report or ESH result in lower prevalence. Studies have shown that the AAP guidelines contribute to a 4.8 %–9.6 % increase in hypertension prevalence compared to the Fourth Report or ESH [16,17]. Additionally, the 2017 AAP guidelines introduced simplified BP screening tables, with values representing the 90th BP percentile and the fifth height percentile by age and sex, capping at 120/80 mm Hg.

In 2020, HC introduced simplified diagnostic thresholds for diagnosing hypertension in children and adolescents: 130/85 mmHg for ages 12–17 and 120/80 mmHg for ages 6–11 [15]. These thresholds were based on data from the Bogalusa Heart Study, which demonstrated that the simplified definition predicts the risk of adult hypertension and subclinical CVD as effectively as the more complex definition [18]. This approach may enhance the screening of hypertensive children to mitigate the risk of adult CVD. The revised definition emphasizes outcome-based criteria rather than relying solely on an arbitrary statistical cutoff, such as the 95th percentile.

There are two major guidelines regarding pediatric hypertension in Asia [14,15]. The Chinese Hypertension League's 2018 guidelines proposed a simplified 'Formula Standard' to facilitate the rapid diagnosis of pediatric hypertension by clinicians. However, they recommend confirming suspected cases identified using the 'Formula Standard' with the 'Table Standard.' The simplified formula for screening hypertension in children aged 3–17 years is as follows: for males, SBP = 100 + 2 × Age and DBP = 65 + Age; for females, SBP = 100 + 1.5 × Age and DBP = 65 + Age. This guideline is based on Chinese-specific normative BP data [14]. Notably, this formula's thresholds are 3–12 mmHg higher than those in the AAP 2017 screening table.

Meanwhile, the Japanese Society of Hypertension (JSH) published their guidelines in 2019, introducing age- and sex-specific thresholds for diagnosing hypertension based on Japanese-specific normative data [15]. JSH defines pediatric hypertension as BP thresholds of ≥120/70 mmHg for preschool children, ≥130/80 mmHg for 1st–3rd graders, ≥135/80 mmHg for 4th–6th graders, ≥140/85 mmHg for 7th–9th grade boys, ≥135/80 mmHg for 7th–9th grade girls, and ≥140/85 mmHg for senior high school boys and girls [15]. According to JSH, pediatric hypertension prevalence ranged from 0 % to 4.4 % across grades and it was 0.9 % in healthy children [19].

The ESH recently released its 2023 ESH guidelines for the management of arterial hypertension, which included a short section on hypertension in children and adolescents [20]. The threshold for hypertension diagnosis in the 2023 ESH guidelines remains unchanged from prior iterations [20].

1.2. Applying BP guidelines to taiwanese youth: key considerations

In 2022, the Taiwan Hypertension Society and the Taiwan Society of Cardiology released a guideline for the management of hypertension [21]. However, this guideline did not address the pediatric population. Therefore, pediatricians in Taiwan rely on international pediatric hypertension guidelines or adapt them to local practices to manage hypertension in children and adolescents effectively.

When evaluating an individual child clinically, variations in guidelines with specific thresholds for diagnosing hypertension can lead to differing diagnoses. For instance, a BP reading of 110/70 is classified as hypertension for a short 7-year-old boy in the United States (AAP threshold for hypertension: 106/68) and Europe (ESH: 106/70). However, the same reading is considered normotensive in Canada (HC: 120/80), China (114/72), and Japan (JSH: 130/80). These discrepancies highlight the importance of applying an appropriate definition when assessing BP in children and adolescents.

The transition from pediatric percentiles to adult diagnostic thresholds introduces additional complexities. With both the AAP and ESH guidelines, this issue is somewhat mitigated when adult hypertension thresholds are lower than pediatric ones. From an epidemiological standpoint, the use of AAP nomograms has been associated with an increased prevalence of pediatric hypertension diagnoses [16].

The JSH guidelines present an additional layer of complexity by distinguishing between reference values for screening and management. Notably, management thresholds are set 10–15 mmHg lower than screening thresholds [15]. This creates challenges in balancing screening thresholds and management criteria, as lower screening thresholds may result in an excessive number of children being classified as hypertensive, complicating post-screening care.

A recent study of 12,469 Taiwanese youth showed that the 2017 AAP guidelines aligned with the 2004 Fourth Report, with perfect agreement in defining hypertension across age groups (1–7, 8–12, and 13–17 years, all $\kappa \geq 0.85$) [22]. While the AAP threshold classified more adolescents as hypertensive, the two guidelines were consistent in their classification. This supports adopting the AAP 2017 nomograms for Taiwanese youth, with a hypertension threshold of 130/80 mm Hg starting at age 13, aligning with adult guidelines, which is considered advisable [23].

Currently, BP screening thresholds for student physical examinations remain inconsistent in Taiwan. The Ministry of Education's "School

Table 1
National and international clinical practice guidelines for pediatric hypertension.

Issuing body	Screen tool	Criteria	Nomogram
European society of hypertension (ESH), 2016 [11]	None	≥95th percentile or ≥ 140/80 (16 y)	2004 fourth report normative BP data
American academy of pediatrics (AAP), 2017 [12]	Screening table	≥95th percentile or ≥ 130/80 (13 y)	New normative BP data (normal weight) using the 4th NHANES data
Chinese hypertension league, 2018 [13]	Formula standard	≥95th percentile	Chinese-specific normative BP data
Japanese society of hypertension (JSH), 2019 [14]	None	≥ age-based static cut point	None
Hypertension Canada (HC), 2020 [15]	None	≥95th percentile or > 120/80 (6–11 y) or >130/85 (12–17 y)	New normative BP data (normal weight) using the 4th NHANES data

BP, blood pressure; NHANES, National Health and Nutrition Examination Survey.

Table 2
Differences in blood pressure definition by different pediatric guidelines.

Categorization	Normotension	Prehypertension/elevated blood pressure	Stage 1 hypertension	Stage 2 hypertension
Fourth report 2004 [9]	<90th percentile	≥90th to <95 percentile	≥95th to <99 percentile+5 mmHg	≥99th percentile+5 mmHg
ESH 2016 [11]	<90th percentile	≥90th to <95 percentile	≥95th to <99 percentile+5 mmHg	≥99th percentile+5 mmHg
<16 years				
>16 years	<130/85	130-139/85-90	140-159/90-99	160-179/100-109
AAP 2017 [12]	<90th percentile	≥90th to <95 percentile or ≥120/80	≥95th to <95 percentile+12 mmHg or 130–139/80-89	≥95th percentile+5 mmHg or ≥140/90
<13 years				
≥13 years	<120/80	120-129/<80	130-139/80-89	≥140/90

ESH, European Society of Hypertension; AAP, American Academy of Pediatrics.

Student Health Screening Workbook" sets a single hypertension threshold of 130/85 mm Hg for all grades from elementary school to senior high school [24]. However, no guidelines recommend a fixed BP cutoff for all children and adolescents. It is recommended to adopt the HC 2020 simplified thresholds for hypertension screening: 130/85 mm Hg for high school students (ages 12–17) and 120/80 mm Hg for elementary school students (ages 6–11).

1.3. Knowledge gaps in pediatric hypertension

Despite advances in pediatric hypertension diagnosis and treatment, significant knowledge gaps remain [25–27]. Key steps in management include accurate BP measurement, confirming the diagnosis, investigating secondary causes, and considering pharmacotherapy or lifestyle changes. The goal is to prevent hypertension-mediated organ damage (HMOD) in childhood and reduce adult CVD risk. A review of current practices reveals limited data and incomplete knowledge in this area. Fig. 1 summarizes these knowledge gaps and outlines the need for strategic approaches to address them.

There is ongoing debate about whether screening for hypertension in youth effectively delays its onset or improves cardiovascular outcomes in adulthood. While the United States Preventive Services Task Force has consistently cited a lack of evidence to support routine pediatric hypertension screening [28,29], all pediatric guidelines continue to recommend annual BP screening for children and adolescents [11–15]. Addressing these gaps is crucial, yet generating the necessary evidence would likely require a decades-long clinical trial involving children randomized to BP screening or no screening—an endeavor that is practically unfeasible given the extensive time and research that would be required. Furthermore, the potential harms of screening must be considered. For example, lower screening thresholds could result in overdiagnosis, complicating post-screening care and management.

For the diagnosis of hypertension, 24-h ambulatory BP monitoring (ABPM) and home blood pressure (BP) measurements can be used to confirm the condition. In children, hypertension diagnosed by ABPM is a better predictor of left ventricular hypertrophy (LVH), one important form of HMOD, compared to office BP [30]. ABPM is crucial for diagnosing white-coat hypertension, masked hypertension, and nocturnal hypertension in pediatric populations [31]. However, the widespread use of ABPM has been limited by its availability and high cost, both in Taiwan and globally. While the 2023 ESH guidelines acknowledge the potential role of home BP assessment in children [21], the availability of validated home BP devices, particularly for young children, remains limited [32]. Consequently, further research is needed to compare the

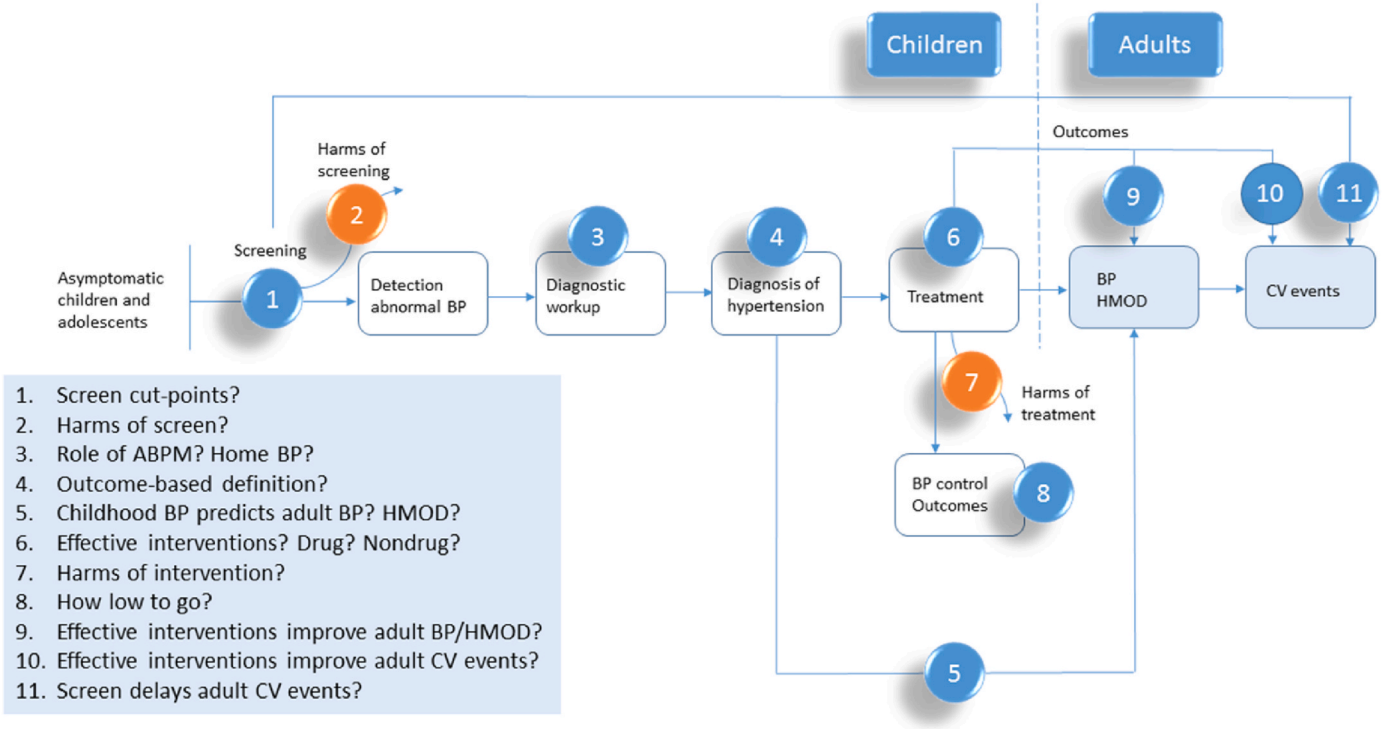

Fig. 1. Diagram illustrating knowledge gaps for pediatric hypertension. ABPM, 24-h ambulatory blood pressure monitoring; BP, blood pressure; HMOD, hypertension-mediated organ damage.

effectiveness of home BP screening versus ABPM in the pediatric population.

As previously noted, one rationale for using a statistical approach to define pediatric hypertension is the lack of direct evidence linking childhood BP levels to adult CVD. Increasing advocacy for BP thresholds that predict adult hypertension, HMOD, and cardiovascular events underscores the need to establish an outcome-based definition.

Another significant knowledge gap lies in the treatment of pediatric hypertension [26,27]. Limited information is available to establish therapeutic goals for both nonpharmacological and pharmacological interventions.

The 2017 AAP guidelines recommend starting hypertension treatment in youth with nonpharmacologic interventions [12]. Medications are advised if BP remains high despite lifestyle changes, it persists, or if LVH is detected on echocardiography. Recommended pharmacologic options include angiotensin-converting enzyme inhibitors (ACEIs), angiotensin II receptor blockers (ARBs), calcium channel blockers (CCBs), and thiazide diuretics in most guidelines [11–15]. Short-term use in children appears safe, but the long-term effects are unknown. Most FDA-approved antihypertensive agents for pediatrics are limited to those ≥6 years [33], based on efficacy from a single trial and pharmacokinetic data. For children <6 years, only two oral drugs are approved, with none being approved for neonates [22].

High BP is particularly prevalent among specific pediatric populations, such as those with chronic kidney disease (CKD) and obesity [34,35]. There is a growing recognition of the pathophysiological interconnectedness of metabolic risk factors, including obesity, diabetes, CKD, and CVD, leading to the conceptualization of cardiovascular-kidney-metabolic (CKM) syndrome [36]. Since hypertension is a key component of CKM syndrome, multimodal approaches targeting hypertension and its associated disorders are essential for effective prevention and treatment.

Furthermore, there is a lack of prospective trials demonstrating that lowering BP to normal levels in youth leads to reduced risk of adult hypertension, HMOD, and CVD. When defining appropriate BP thresholds [37], it is also crucial to address the potential harms associated with treatment.

Additionally, there is no consensus on international guidelines for diagnosing hypertension in infants (<12 months) [38]. BP norms differ by age—first day [39], first 2 weeks [40], and beyond—yet standardized diagnostic criteria remain unclear. The 1987 Second Task Force Report is commonly referenced for infants >2 weeks old [41], but the most effective diagnostic approach and the long-term impact of early BP measurements, particularly in preterm, low birth weight, and congenital heart disease infants, remain uncertain.

Drug therapy is recommended when a neonate's BP consistently reaches the 99th percentile, while older infants should follow Task Force guidelines [41]. However, few antihypertensive medications have been studied in neonates, and current recommendations rely on expert opinion rather than evidence. Randomized trials are urgently needed. Case reports indicate varied use of vasodilators, diuretics, ACEIs, beta-blockers, and CCBs [38].

1.4. Conclusions and future perspectives

On December 29, 2024, the Taiwan Pediatric Nephrology Society and the Taiwan Hypertension Society convened a meeting to discuss pediatric hypertension, with a particular emphasis on identifying and addressing knowledge gaps in Taiwan. This article highlights key considerations, reviews current practices in managing pediatric hypertension, and explores strategies for the medical and research communities to bridge these knowledge gaps.

The global prevalence of hypertension and CVD is unlikely to improve without concerted efforts to address and mitigate the burden of hypertension starting in childhood. Early intervention is critical, as childhood hypertension often tracks into adulthood, contributing to long-term health complications such as stroke, kidney disease, and CVD. For this reason, collaboration between pediatricians and adult physicians is essential to ensure that BP measurement becomes a routine and standardized part of clinical practice across all age groups. This collaboration should extend beyond a small group of specialists to include a broader network of healthcare providers, including general practitioners, nurses, and public health professionals.

Efforts to prevent and manage hypertension in children should focus on early detection, coordinated treatment, education, and lifestyle changes. A lifespan approach is essential, with an emphasis on prevention through effective interventions and further research to bridge existing knowledge gaps. Addressing childhood hypertension can prevent early complications, reduce disease burden, and lower the global prevalence of CVD. Public health campaigns, policy changes, and improved healthcare access are critical to combating hypertension early. Collaboration among healthcare providers, policymakers, and communities is key to achieving better cardiovascular outcomes across all ages.

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