



# Difference in the Prevalence of Elevated Blood Pressure and Hypertension by References in Korean Children and Adolescents

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The prevalence of pediatric hypertension and obesity has increased over the past decades. Pediatric hypertension and obesity are associated with adult hypertension, metabolic syndrome, and cardiovascular disease. There are two main pediatric blood pressure (BP) classification guidelines, the “Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents” (AAP 2017) and “2016 European Society of Hypertension guidelines for the management of high BP in children and adolescents” (ESH 2016). No study has classified Korean youths with cardiometabolic risk. This study analyzed the prevalence of high BP according to AAP 2017 (elevated BP and hypertension) and ESH 2016 (prehypertension and hypertension) in Korean children. Additionally, the cardiometabolic risk factors (CMRFs) were compared between children who were hypertensive in AAP 2017 but normotensive in ESH 2016 (upward reclassified) to those who were normotensive in both AAP 2017 and ESH 2016. Data were extracted from the Korea National Health and Nutrition Examination Survey, 2016–2018. A total of 1,858 children aged 10–17 years were included in the analysis. The prevalence of elevated BP/prehypertension and hypertension was 4.1 and 6.5% by ESH 2016, and 8.9 and 9.4% by AAP 2017 in Korean youth, respectively. The AAP 2017 reclassified 11.9% of youth in the upper BP class. When those upward reclassified youth were compared to those who were normotensive in both AAP 2017 and ESH 2016, reclassified youth were male predominant (77.1 vs. 49.6%,  $p < 0.001$ ), older (14.6 vs. 13.8,  $p < 0.001$ ) and showed higher body mass index (BMI) z-score (0.77 vs. 0.15,  $p < 0.001$ ) and more overweight/obesity (14.0/30.6 vs. 13.3/6.4%,  $p < 0.001$ ) and severe CMRFs (triglyceride 83.2 vs. 72.9 mg/dL,  $p = 0.011$ ; high-density lipoprotein cholesterol 47.3 vs. 51.1 mg/dL,  $p < 0.001$ ; alanine transaminase 21.7 IU/L vs. 14.7 IU/L,  $p = 0.001$ , uric acid 5.89 vs. 5.22 mg/dL,  $p < 0.001$ ; metabolic syndrome 13.2 vs. 1%,  $p < 0.001$ ). In conclusion, AAP 2017 showed a higher prevalence of abnormal BP in Korean youth, and those upward reclassified by AAP 2017 were more obese and had severe CMRFs than normotensive Korean children. The AAP 2017 could allow the early detection of Korean youth with more CMRFs.

**Keywords:** hypertension, pediatrics - children, American Academy of Pediatrics (AAP), European society of hypertension (ESH), Korea (rep.), cardiometabolic risk

## INTRODUCTION

Pediatric hypertension is a worldwide growing public health problem that is strongly associated with childhood obesity (1). Although the actual secular trend of hypertension prevalence varies from country to country, the evidence that childhood hypertension predisposes to adulthood hypertension, and metabolic syndrome (MS), and is the leading cause of adult mortality and cardiovascular disease (CVD), has highlighted the importance of recognizing pediatric hypertension (1–6). The diagnosis of pediatric hypertension is based on the normative blood pressure (BP) distribution measured by an auscultatory method in healthy children according to sex, age, and height.

Currently, there are two main updated pediatric hypertension guidelines; Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents (AAP 2017) and 2016 European Society of Hypertension guidelines for the management of high blood pressure in children and adolescents (ESH 2016) (7, 8). The main differences between these two guidelines are: First, the BP classification criteria. Second, the inclusion (ESH 2016) and exclusion (AAP 2017) of overweight and obese children in normative reference to adjust for the impact of obesity on BP. Third, the age at which the adult hypertension definition applies (13-years-old for AAP 2017 vs. 16-years-old for ESH 2016) and the BP cut-off value in adults (9). As blood pressure differs according to race, ethnicity, and distribution of obesity, it is important to decide which guidelines should be applied locally (10). Most recently published studies have shown an increasing secular trend in hypertension prevalence and BMI in Korean children (11). The Korean Working Group of Pediatric Hypertension published a normotensive BP reference table excluding overweight and obese children based on data from the Korea National Health and Nutrition Examination Survey (KNHANES) 1998–2016 (12). However, a discussion on which BP classification criteria from the guidelines above should be applied to Korean children is still in progress. Several studies have compared cardiometabolic profile between AAP 2017 and ESH 2016 in other countries (13–17). Most studies showed better coverage of children with a cluster of cardiometabolic risks, such as hypertension in the AAP 2017 guideline (14, 15). This study analyzed the difference in hypertension prevalence and cardiometabolic risk profile between AAP 2017 and ESH 2016 in Korean youth using the KNHANES 2016–2018 data.

## MATERIALS AND METHODS

### Study Participants

This study was performed using data obtained from the KNHANES 2016–2018. The KNHANES is a nationally representative survey that has been conducted cross-sectionally since 1998 by the Korea Disease Control and Prevention Agency (KDCA, formerly the Korea Centers for Disease Control and Prevention) and the Ministry of Health and Welfare.

The detailed methods for the KNHANES data collection are described elsewhere (18).

A total of 24,269 individuals (11,071 males, 42.6%) were enrolled in the KNHANES from 2016 to 2018. The overall response rate for the survey was 76.6%. Among them, 1,858 children and adolescents aged 10–17 years were selected as participants for the present study, after excluding the following subjects: no anthropometric data ( $n = 130$ ), no BP data ( $n = 134$ ), diastolic BP values less than 30 mm Hg ( $n = 3$ ), estimated glomerular filtration rate (GFR) by Schwartz equation  $<60$  mL/min/1.73 m<sup>2</sup> (19) ( $n = 0$ ), or pregnancy ( $n = 0$ ).

Among participants with normal BP according to ESH 2016 ( $n = 1,655$ ), clinical data were compared between normal ( $n = 1,508$ ) and abnormal ( $n = 147$ ) BP by AAP 2017. Among them, in those with fasting blood samples ( $n = 1,454$ , normal BP 1,325, abnormal BP 129), subgroup analysis was performed to compare cardiometabolic risk factors (CMRFs) and MS.

The KNHANES protocol was approved by the Institutional Review Board of the KDCA. Informed consent was obtained from all the participants and/or legal guardian(s). The present study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB No. X-1906/547-903). All procedures were performed in accordance with the principles of Declaration of Helsinki.

### Measurement of Anthropometric and Laboratory Data

Anthropometric data were measured by well-trained medical personnel using calibrated equipment according to standardized protocols. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 225, Seca, Hamburg, Germany). Weight was measured to the nearest 0.1 kg using an electronic balance (GL-6000–20, G-tech, Seoul, Korea). Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters. Waist circumference (WC) was measured to the nearest 0.1 cm using a flexible tape at the midpoint between the lowest costal margin and the uppermost tip of the iliac crest. Height and BMI were transformed to a standard deviation score (z-score) using the CDC 2000 Growth Chart (20, 21). Overweight and obesity was diagnosed when a participant's BMI was in the 85th to  $<95$ th percentile and the  $\geq 95$ th percentile for corresponding sex and age, respectively. Abdominal obesity was defined when WC  $\geq 90$ th percentile for corresponding sex and age (22).

Blood samples were drawn from participants by trained nurses after an overnight fast. Collected samples were properly prepared, transported to the Central Laboratory and analyzed within 24 h. Plasma glucose, high-density lipoprotein cholesterol (HDL-C), triglyceride, and alanine transaminase (ALT), and uric acid levels were measured using a Hitachi Automatic Analyzer 7600-210 (Hitachi, Tokyo, Japan). Glycated hemoglobin was measured using high-performance liquid chromatography (Tosoh, Tokyo, Japan), which is a certified method in the National Glycohemoglobin Standardization Program.

## Measurement of Blood Pressure and Definition of Hypertension

In the KNHANES, BP was measured using a mercury sphygmomanometer after resting for at least 5 min in a sitting position [Baumanometer Wall Unit 33(0850), W. A. Baum, New York, USA] with a cuff appropriate for arm circumference. All BP measurements were performed three times on the right arm. The average values of the second and third measurements of systolic and diastolic BP were used for subsequent analyses. Age-, sex-, and height-specific BP percentiles were determined for systolic and diastolic BP and classified as normal (<90th percentile), elevated BP ( $\geq 90$ th and <95th percentile), the hypertension ( $\geq 95$ th percentile) for age under 13 in AAP 2017 (8), and 16 in ESH 2016 guidelines (7). The static BP cut-off value was used to define normal, elevated BP, and hypertension for those older than these ages. (In AAP 2017, <120/<80 mm Hg, 120/<80 to 129/<80 mm Hg, and  $\geq 130/80$  mm Hg, respectively. In ESH 2016, <130/85 mm Hg, 130–139/85–90 mm Hg, and  $\geq 140/90$  mm Hg, respectively). Among participants who were classified as normotensive by ESH 2016, those who are reclassified as hypertensive in AAP 2017 were described as “Upward reclassified,” and those who remained in normotension in AAP 2017 were described as “Persistent normotensive.” The high BP is defined when BP value is above normotensive.

## Definition of Metabolic Syndrome

MS was defined using criteria proposed by Cook et al. (23). The components of MS criteria are WC  $\geq 90$ th percentile, fasting glucose  $\geq 110$  mg/dL, BP  $\geq 90$ th percentile, triglycerides  $\geq 110$  mg/dL, HDL-C  $\leq 40$  mg/dL. Definition of MS is  $\geq$  three among five criteria above mentioned.

## Statistical Analysis

Statistical analyses were performed using Stata 16.1 software (StataCorp LP, College Station, Texas, USA). A *svy* command with appropriate sample weights was used for the analysis. All data were expressed as weighted means with standard error for continuous variables and as the number of subjects with weight percentage for categorical variables. Student *t*-tests were used to compare continuous variables. Chi-squared tests were used to compare categorical variables. *P*-values < 0.05 were considered statistically significant.

## RESULTS

### Clinical Characteristics of Study Participants

Among the 1,858 participants, males were 972 (52.4%). Boys showed a higher height z-score, BMI z-score, proportion of overweight/obesity, WC, abdominal obesity, systolic BP and increased consumption of dietary factors (Table 1).

### Prevalence of Hypertension by Different Criteria

The prevalence of hypertension was 9.4% (boys, 11.1%; girls, 7.5%) by AAP 2017 and 4.1% (boys, 4.5%; girls, 3.5%) by ESH

2016 (Table 2). Boys showed higher prevalence of hypertension and elevated BP in AAP 2017.

Among participants, 87.2% (boys, 82.9%; girls, 91.9%) showed the same BP category in both criteria (Table 3). A total of 11.9% (boys, 16.6%; girls, 6.8%) participants were underestimated using ESH 2016. In contrast, only 0.9% (boys 0.5%; girls, 1.2%) were overestimated using ESH 2016.

In non-obese youth, 90.6% (boys, 87.9%; girls, 93.2%) showed the same BP category in both criteria (Supplementary Table 1). A total of 8.5% (boys, 11.4%; girls, 5.9%) non-obese youth were underestimated using ESH 2016. In contrast, only 0.8% (boys 0.8%; girls, 0.8%) were overestimated using ESH 2016.

To analyze the CMRF distribution in high BP children according to AAP 2017 and ESH 2016, the prevalence of high BP in children with and without CMRF (overweight/obesity or metabolic abnormalities) was evaluated. A total of 1,619 participants with fasted samples were included. In AAP 2017, among 17.5% of high BP children, 52.0% had more than one CMRF. The prevalence of high BP in children with and without CMRF were 27.4% and 12.5%, respectively ( $p < 0.001$ ). In ESH 2016, among 9.5% of high BP children, 58.3% had more than one CMRF. The prevalence of high BP in children with and without CMRF were 16.8% and 5.9%, respectively ( $p < 0.001$ ).

### Comparison Between Upward Reclassified Youth and Persistent Normotensive Youth

Table 4 shows a comparison between upward reclassified youth and persistent normotensive youth. Among 1,655 subjects with normal BP by ESH 2016, 1,508 were persistent normotensive and 147 were upward reclassified. The upward reclassified youth showed male predominance, older age, higher BMI z-score, and more overweight/obesity. In the subgroup analysis, participants with fasting samples revealed elevated CMRFs including triglyceride, HDL-C, ALT, uric acid and MS.

Comparable results were shown when 82 upward reclassified non-obese youth and 1,186 persistent normotensive non-obese youth were compared. The upward reclassified non-obese youth showed male predominance, older age, and had lower estimated GFR. In addition, higher fasting glucose, lower HDL-C, higher uric acid, and prevalent MS were shown in upward reclassified non-obese youth (Supplementary Table 2).

## DISCUSSION

This study analyzed the prevalence of high BP according to the AAP 2017 (elevated BP and hypertension) and ESH 2016 (prehypertension and hypertension) guidelines in Korean children. We noted that the prevalence of hypertension was lower in Korea than in other countries from previous studies. In Korean children, approximately 12% in the AAP 2017 and 1% in the ESH 2016 were reclassified in the upper BP class. The AAP 2017 might potentially identify more children with prominent cardiometabolic risk factors.

In adults, hypertension is an important risk factor for CVD, the leading cause of death worldwide (23). Intensive control of hypertension can lower the risk of CVD (24). The trajectory

**TABLE 1** | Demographic characteristics of study participants.

Variables	Total (n = 1,858)	Boys (n = 972, 52.4%)	Girls (n = 886, 47.6%)	P value
Age (year)	13.8 ± 0.1	13.8 ± 0.1	13.7 ± 0.1	0.402
Height z-score	0.39 ± 0.03	0.53 ± 0.04	0.23 ± 0.04	<0.001
BMI z-score	0.28 ± 0.03	0.40 ± 0.04	0.16 ± 0.04	<0.001
BMI category				
Obesity	209 (10.7%)	159 (15.3%)	50 (5.7%)	<0.001
Overweight	281 (14.4%)	165 (15.8%)	116 (12.7%)	
Waist circumference (cm)	69.7 ± 0.3	72.4 ± 0.4	66.8 ± 0.3	<0.001
Abdominal obesity	178 (9.0%)	147 (14.1%)	31 (3.4%)	<0.001
Systolic blood pressure (mm Hg)	108.1 ± 0.3	110.4 ± 0.4	105.6 ± 0.4	<0.001
Diastolic blood pressure (mm Hg)	66.1 ± 0.2	66.3 ± 0.3	66.0 ± 0.3	0.452
Dietary factors				
Calories (Kcal/d)	2100 ± 26	2339 ± 37	1838 ± 28	<0.001
Total fat (g/d)	57.6 ± 1.1	64.4 ± 1.7	50.1 ± 1.3	<0.001
Carbohydrates (g/d)	313.8 ± 4.1	346.7 ± 5.4	277.8 ± 4.6	<0.001
Protein (g/d)	76.5 ± 1.2	86.5 ± 1.7	65.6 ± 1.3	<0.001
Fiber (g/d)	20.5 ± 0.4	22.6 ± 0.5	18.1 ± 0.4	<0.001
Water (g/d)	773.7 ± 15.5	838.8 ± 21.8	702.2 ± 19.1	<0.001
Sodium (mg/d)	3071 ± 53	3473 ± 73	2630 ± 61	<0.001

BMI, body mass index.

Data were expressed as weighted mean ± SE for continuous variables or number (weighted percent) for categorical variables.

**TABLE 2** | Prevalence of hypension by different criteria.

Criteria	Category	Total	Boys	Girls	P-value
AAP 2017	<90th	81.7 (79.5, 83.7)	77.1 (73.8, 80.1)	86.7 (84.0, 89.0)	<0.001
	≥90th to <95th	8.9 (7.6, 10.6)	11.8 (9.6, 14.4)	5.8 (4.4, 7.7)	
	≥95th	9.4 (7.9, 11.2)	11.1 (8.9, 13.8)	7.5 (5.7, 9.8)	
ESH 2016	<90th	89.4 (87.6, 91.1)	89.1 (86.6, 91.3)	89.8 (87.3, 91.9)	0.637
	≥90th to <95th	6.5 (5.3, 7.9)	6.4 (4.8, 8.4)	6.6 (5.0, 8.6)	
	≥95th	4.1 (3.1, 5.3)	4.5 (3.2, 6.4)	3.5 (2.3, 5.5)	

Data was expressed as weighted percent (95% CI).

AAP 2017, the 2017 American Academy of Pediatrics Guideline; ESH 2016, the 2016 European Society of Hypertension Guideline.

**TABLE 3** | Distribution of blood pressure of category by sex and criteria.

Group	ESH 2016	AAP 2017			P-value
		<90th	≥90th to <95th	≥95th	
Total	<90th	80.9 (78.7, 83.0)	6.5 (5.3, 8.0)	2.0 (1.4, 2.9)	<0.001
	≥90th to <95th	0.8 (0.4, 1.4)	2.3 (1.7, 3.2)	3.4 (2.5, 4.6)	
	≥95th	0	0.1 (0.02, 0.4)	4.0 (3.0, 5.2)	
Boys	<90th	76.6 (73.3, 79.6)	10.0 (8.0, 12.4)	2.6 (1.6, 4.1)	<0.001
	≥90th to <95th	0.5 (0.2, 1.5)	1.8 (1.1, 2.9)	4.0 (2.7, 5.8)	
	≥95th	0	0	4.5 (3.2, 6.4)	
Girls	<90th	85.7 (82.8, 88.2)	2.7 (1.7, 4.3)	1.4 (0.8, 2.4)	<0.001
	≥90th to <95th	1.0 (0.5, 2.0)	2.9 (1.9, 4.3)	2.7 (1.8, 4.1)	
	≥95th	0	0.2 (0.05, 0.8)	3.3 (2.1, 5.3)	

Data was expressed as weighted percent (95% CI).

AAP 2017, the 2017 American Academy of Pediatrics Guideline; ESH 2016, the 2016 European Society of Hypertension Guideline.

phenomenon indicates that childhood BP influences adulthood BP emphasizing the importance of detecting hypertension in

children who are at risk of developing CVD in future life to prevent adulthood hypertension and CVD (2–6, 25, 26).

**TABLE 4** | Comparison between subjects with normal blood pressure by ESH 2016 criteria.

	Persistent normotensive (n = 1,508)	Upward reclassified (n = 147)	P-value
Sex, male, n (%)	744 (49.6%)	112 (77.1%)	<0.001
Age (year)	13.8 ± 0.1	14.6 ± 0.2	<0.001
Height z-score	0.37 ± 0.03	0.41 ± 0.08	0.641
BMI z-score	0.15 ± 0.03	0.77 ± 0.09	<0.001
BMI category			
Obesity	114 (6.4%)	41 (30.6%)	<0.001
Overweight	208 (13.3%)	24 (14.0%)	
Abdominal obesity	95 (5.4%)	35 (26.6%)	<0.001
Systolic blood pressure (mm Hg)	105.0 ± 0.2	120.0 ± 0.5	<0.001
Diastolic blood pressure (mm Hg)	64.4 ± 0.2	72.2 ± 0.7	<0.001
Estimated GFR (mL/min per 1.73 m <sup>2</sup> )	144.0 ± 0.8	144.1 ± 1.9	0.989
Glucose (mg/dL)*	91.4 ± 0.2	92.5 ± 0.7	0.140
HbA1c (%)*	5.35 ± 0.01	5.33 ± 0.02	0.381
Triglyceride (mg/dL)*	72.9 ± 1.2	83.2 ± 4.2	0.011
HDL-C (mg/dL)*	51.1 ± 0.3	47.3 ± 0.7	<0.001
Alanine transaminase (IU/L)*	14.7 ± 0.6	21.7 ± 2.0	0.001
Uric acid (mg/dL)*	5.22 ± 0.04	5.89 ± 0.14	<0.001
Metabolic syndrome, n (%)*	14 (1.0%)	16 (13.2%)	<0.001

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol.

Data were expressed as weighted mean ± SE for continuous variables or number (weighted percent) for categorical variables.

\*n = 1,454 (normal 1,325, abnormal 129).

Triglyceride and HDL-C were log-transformed for analysis and described as geometric mean ± SE.

The cardiovascular effect of BP elevation in children is shown in subclinical findings such as left ventricular geometry changes and systolic and diastolic dysfunction (27–29). In children, improvement of left ventricular geometry changes has been shown after hypertension is treated with antihypertensive medication (30). Additionally, pediatric obesity is strongly associated with BP elevation in children and poor cardiovascular outcomes in adulthood (1, 31–33). When childhood obesity is adequately managed, CVD in adulthood also decreases (31).

There is no doubt that hypertension and obesity in childhood are risk factors for CVD in adults (2–6, 25, 26). However, as children scarcely present with actual CVD, the exact BP value that increases CVD is not known. Efforts have been made to define hypertensive children with cardiometabolic risk, and presently, there are two main pediatric hypertension guidelines, the AAP 2017 and ESH 2016 (7, 8). After the AAP 2017 was published, many studies compared the prevalence and cardiometabolic risk profile between the AAP 2017 and ESH 2016 to find adequate hypertension diagnosis criteria in children (13–17, 34). Pediatric BP is influenced by several factors, such as gender, obesity, nutrition, socioeconomic status, race, and ethnicity (10, 35). The AAP 2017 and ESH 2016 define hypertension primarily in children in the United States and Europe (7, 8). There are differences in influencing factors of BP between Western and Korean children, so the optimal guidelines for application in Korean children and adolescents are unknown. This study is the first comparative analysis of pediatric hypertension guidelines for Korean youth.

There were clinical differences by sex in the Korean pediatric population. Korean boys were taller and more obese and had

higher systolic BP than girls. In addition, boys showed higher daily calorie, water, and sodium intake than girls. When the guidelines were applied to Korean children, elevated BP/pre-hypertension and hypertension prevalence increased from 6.5% to 8.9% and 4.1% to 9.4% by the AAP 2017 compared to ESH 2016. This study showed a lower prevalence of hypertension than that reported in previous studies from Spain (AAP 2017 vs. ESH 2016, 10.6% vs. 6.6%) (13) and China (AAP 2017 vs. ESH 2016, 8.3–14.5% vs. 5.0%) (16). Studies conducted in Italy showed a higher prevalence (AAP 2017 vs. ESH 2016, 31–35% vs. 35–41%), as these studies analyzed high-risk children who were overweight/obese or referred from primary physicians for BP elevation (14, 17). An increase in the prevalence of hypertension using the AAP 2017 guidelines was consistently observed in all the studies.

Statistically significant differences by gender were observed only in elevated BP (boys 11.8% vs. girls 5.8%) and hypertension (boys 11.1% vs. girls 7.5%) by the AAP 2017 in this study. However, ESH 2016 showed no gender differences in prevalence. Generally, boys tend to have higher BP values and more prevalent hypertension than girls (8, 36, 37). Besides this gender effect on BP, the clinical characteristics of Korean boys, higher obesity and high sodium intake, might have impacted the prevalence as only AAP 2017 showed gender differences. Obesity and high sodium intake strongly affect the prevalence of hypertension (33, 38). As CMRF effects on BP value, we also compared the prevalence of high BP in children with and without CMRF. Both AAP 2017 and ESH 2016 showed the more prevalent high BP in children with CMRF. In AAP 2017, the prevalence increased in both with and without CMRF children. These findings could raise the concern

of overdiagnosis (false positive) by lowering the BP threshold in AAP 2017. However, CMRF is not the outcome of BP elevation. The clinical effects of these high BP children without CMRF need to be studied.

When these guidelines were compared in Korean children, ~12% and 1% were reclassified in the upper BP class in AAP 2017 and ESH 2016, respectively. A similar trend of a higher proportion of upward reclassification by AAP 2017 is shown in Italian overweight/obese children reported by Di Bonito et al. (15).

We compared children underestimated using ESH 2016 (upward reclassified by AAP 2017) to those consistently classified as normotensive in the AAP 2017 and ESH 2016. In a previous study by Di Bonito et al., upward-reclassified children were older, had higher BMI, higher insulin resistance, higher triglyceride, TC/HDL-C ratio, left ventricular (LV) mass index, and lower HDL-C compared to children steadily classified as normotensive in both guidelines (15). Similar to Di Bonito et al. (15), children reclassified upward by AAP 2017 in this study were more likely to be male, older, obese, and had poor metabolic factors (higher triglyceride, ALT, and uric acid; lower HDL-C; more prevalent MS) than those who remained normotensive by AAP 2017. These findings indicate that despite differences in race and ethnicity, applying AAP 2017 in Korean children still showed similar trends in Western children. In addition, AAP 2017 revealed more children with a cluster of cardiometabolic risks, such as hypertension. In other words, AAP 2017 might sensitively detect Korean youth who are obese and have other co-existing metabolic risks who were underdiagnosed by normotensive references derived from both normal and overweight/obese children. It provides public health opportunities to recognize Korean children with clusters of cardiometabolic risks, including obesity. In contrast to these findings, Antolini et al. reported there was no significant difference in detecting left ventricular hypertrophy between AAP 2017 and ESH 2016 when weight was adjusted within children who were obese or suspected to have BP elevation (17). Therefore, we analyzed the clinical difference of upward reclassified non-obese youth and persistent normotensive non-obese youth. Approximately 9% and 1% of non-obese youth were reclassified in the upper BP class in AAP 2017 and ESH 2016. Even after removing the impact of obesity, still upward reclassified youth showed poor CMRF. Globally, the prevalence of pediatric obesity has increased in the past decades, and a similar trend has been observed in Korean children (39–42). In the COVID-19 pandemic and lockdown era, children are more at risk of becoming obese and developing metabolic risks (43). Therefore, with the increasing obesity in Korean children, the AAP 2017 might potentially identify more children with prominent cardiometabolic risk factors.

This study has a strength because KNHANES is a national survey representing the Korean health and nutrition state, and this study presents the national prevalence of hypertension in children. Except for the study from China by Fan et al. (16), which analyzed hypertension prevalence in the national cohort, other previous studies compared the AAP 2017

and ESH 2016 in high-risk children or children referred for BP elevation (13–15, 17). This study is the first to evaluate cardiometabolic risk between AAP 2017 and ESH 2016 nationwide.

However, this study has some limitations. The KHANES has a cross-sectional design, and BP was measured only three times daily. Hypertension is diagnosed when BP elevation persists on more than three separate occasions, and when BP is measured in one event, it could overestimate the prevalence. Therefore, the actual prevalence of hypertension may be low. Additionally, no study has confirmed the causal relationship between pediatric hypertension and CVD in adulthood. We speculated that adult cardiometabolic risk is broadly known as subclinical surrogate markers such as obesity, MS, dyslipidemia, and LV geometry change (2–6, 25). Therefore, the surrogate markers discussed in this study might not be the actual risk of CVD development in later life. An ongoing cohort study evaluated the effect of pediatric hypertension on CVD (44). In the future, we might have a chance to determine whether our speculation is adequate.

In conclusion, this is the first study to compare the AAP 2017 and ESH 2016 in Korean children. The use of the AAP 2017 in Korean children may allow clinicians to diagnose hypertension in children with clusters of cardiometabolic risks and provide early intervention for risk control and prevention in the youth.

## DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. All raw data used in the present study are available from the KNHANES webpage (<https://knhanes.kdca.go.kr/knhanes/main.do>) with the permission of the KDCA.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Korea Disease Control and Prevention Agency and Seoul National University Bundang Hospital. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

HC and JHK contributed to conception and design of the study. JHK organized the database and performed the statistical analysis. JYK wrote the first draft of the manuscript. JYK, HC and JHK wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmed.2022.793771/full#supplementary-material>

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