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Assessment of cardiovascular disease risk factors in Korean children: impact of various pediatric hypertension guidelines and application of the Korean blood pressure reference

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Abstract

Background The global rise in pediatric hypertension (HTN) is a significant concern as it serves as a precursor to cardiovascular disease (CVD). To address this, we performed a comparative analysis of two guidelines for pediatric HTN: the 2017 American Academy of Pediatrics (AAP) and the 2016 European Society for Hypertension (ESH), applying the Korean blood pressure (BP) reference specifically to the Korean pediatric population.

Methods Data from 2,060 children and adolescents aged 10–18 years from the Korean National Health and Nutrition Examination Survey (2016–2018) were analyzed. BP was classified according to the AAP, the ESH, and the Korea Regional BP Classification (KRC). High BP was defined as BP exceeding the normotensive range.

Results The prevalence of high BP in Korean youth was significantly higher according to the AAP group than that in the ESH group (19.5% vs. 10.6%, $P < 0.0001$). Variations in prevalence were noted based on age, sex, and obesity. No significant differences were observed between the AAP and KRC groups in terms of high BP prevalence. The application of the AAP and KRC provided a more comprehensive reflection of CVD risk factors, including obesity and metabolic profiles, compared to the ESH. The KRC showed a tendency to classify more non-obese individuals as having elevated BP, although this difference was not statistically significant.

Conclusions In comparing the AAP, ESH, and KRC criteria in the Korean pediatric population, the KRC demonstrated a tendency to identify individuals with CVD risk factors as having high BP. This finding suggests that using the KRC as the criterion for high BP may facilitate earlier intervention in the management of CVD risk.

Keywords Cardiovascular disease, Korean population, Pediatric hypertension

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Background

The increasing prevalence of elevated blood pressure (BP) among youth is becoming a major public health concern worldwide [1–3]. High BP during childhood can lead to early structural or functional changes in vital organs, known as target organ damage (TOD), which may have long-term cardiovascular (CV) implications [4–8]. The clinical assessment of TOD involves markers such as left ventricular hypertrophy (LVH) and microalbuminuria [7, 8]. Uncontrolled BP elevation increases the prevalence of TOD, whereas well-controlled BP can mitigate these risks [9].

While evidence links subclinical TOD in adulthood to clinical CV disease (CVD), the direct association between childhood exposure to CVD risk factors and later-life CVD remains unclear [10–13]. An ongoing study is currently evaluating childhood BP levels, aiming to predict future CVD morbidity and mortality [14]. Similarly, we assessed the consequences of childhood exposure to CVD risk factors based on relevant studies. Some studies have found that addressing high blood pressure in early childhood improves cardiovascular disease risk and outcomes both in childhood and adulthood [15–19]. These studies show that childhood exposure to CVD risk factors, such as high BP, increases the risk of adult CVD [20]. High BP in childhood is associated with adulthood hypertension (HTN), CVD risk factors, and metabolic syndrome (MS), all of which are modifiable risk factors for CVD and mortality in adults [21, 22]. Therefore, defining BP elevation in youth is critical for preventing CVD in adults.

Traditionally, the diagnosis of elevated BP in the pediatric population is based on statistical definitions using the distribution of normotensive BPs, measured by the auscultatory method, according to sex, age, and height in healthy children. We investigated the differences between the American Academy of Pediatrics (AAP) and European Society for Hypertension (ESH) guidelines for diagnosing BP elevation in Korean pediatric populations [23, 24]. These guidelines differ in several ways. The AAP introduced a normotensive BP reference table that excluded data from overweight and obese children to prevent bias from obesity in BP measurements. They also applied static cutoff values from the adult guidelines at a younger age than the ESH. In response to the AAP, Kim et al. [25] developed a normal-weight BP reference table for Korean youth. However, no BP classification criteria have been proposed specifically for Korean pediatric populations.

In this study, we adapted the AAP BP classification criteria by incorporating a normal-weight Korean BP reference table and creating the Korea Regional BP Classification (KRC). Our aim was to evaluate the prevalence of BP elevation in Korean children using various classification criteria and to investigate the variations in CV risk factor distribution based on these criteria.

Methods

Study population

The data for this study were derived from the Korean National Health and Nutritional Examination Survey (KNHANES) conducted by the Korea Disease Control and Prevention Agency (KDCA) from 2016 to 2018. The KNHANES used a multistage clustered probability design to select its target population, and sample weights were assigned to participants to ensure the sample accurately represented the broader Korean population. The detailed survey design and data resource profiles are described elsewhere [26]. We included children aged 10–18 years, excluding those without available height or BP values. Ultimately, the analysis focused on 2,060 children from the KNHANES dataset to investigate the prevalence of elevated BP (Supplementary Fig. 1). The KNHANES protocol was approved by the Institutional Review Board of the KDCA. Written informed consent was obtained from all participants and/or their legal guardians. The present study was approved by the Institutional Review Board (IRB) of Samsung Medical Center (IRB number 21-10-074).

Clinical and laboratory measurements

In the KNHANES, skilled medical personnel conducted anthropometric measurements of participants, including body weight, height, and waist circumference. Age- and sex-specific z-scores for weight, height, and body mass index (BMI) were computed using Lambda Mu Sigma tables from the KDCA [27]. These z-scores were then converted into age- and sex-specific percentiles. Overweight and obesity were defined as a BMI within the 85–94th percentile and ≥ 95th percentile, respectively, based on the KDCA criteria.

BP was measured using a mercury sphygmomanometer. Three systolic BP and diastolic BP (DBP) readings were recorded, and final values were obtained by averaging the second and third measurements. The DBP was measured based on the fifth Korotkoff sound. BP classification was performed according to the AAP [23] and ESH [24] guidelines, using normotensive reference tables from each guideline (Supplementary Table 1). The KRC, which employs the AAP BP classification using the normotensive reference table from normal-weight Korean youth extracted from Kim et al. [25], was also employed. High BP was defined as BP greater than the normotensive BP. BP was additionally analyzed according to three age groups: <13, 13–16, and ≥ 16 years.

Anthropometric and laboratory data were analyzed to assess CV risk factors. Abnormal cutoff points for total cholesterol (TC), high-density lipoprotein (HDL),

low-density lipoprotein (LDL), triglycerides (TG), fasting blood glucose, and hemoglobin A1c were defined based on the guidelines of the National Institutes of Health and the American Diabetes Association [28]. MS was defined based on the International Diabetes Federation criteria, which incorporates central obesity and two or more risk factors [29]. Central obesity was determined using Korean waist reference data [30].

CV risk factor profile differences between guidelines

To assess the differences in CV risk factors among children with high BP according to different BP classifications, a comparative analysis was conducted. A subset of 1,799 pediatric participants with complete CV risk factor data was used for this assessment. We compared normotensive individuals to those with high BP according to each criterion. Individuals initially classified as normotensive based on one criteria but reclassified as having high BP under a different criteria were designated as "upwardly reclassified" or "upwardly high." Those who remained normotensive under both criteria were categorized as "consistently normotensive." These two groups—"upwardly reclassified/high" and "consistently normotensive"—were then compared in the analysis. The groups classified as upwardly reclassified/high were compared with age-, sex-, and height-matched consistently normotensive individuals (Supplementary Tables 2–4).

Table 1 Demographic and clinical characteristic of study population, weighted

Characteristic	Participants ($n=2,060$)[a]	Weighted population[b]
Male	1073	52.1 (49.8–54.3)
Age, years	13.8	14.3 (0.07)
Overweight	220	9.9 (8.4–11.3)
Obese	253	12.5 (10.7–14.2)
Ht z-score	0.5	0.5 (0.03)
Wt z-score	0.3	0.3 (0.03)
BMI z-score	0.08	0.07 (0.04)
WC, cm ($n=2059$)	69.7	70.3 (0.3)
SBP, mmHg	108.1	108.5 (0.3)
DBP, mmHg	66.1	66.6 (0.2)
TC (mg/dL) ($n=1,813$)	164.9	164.6 (0.8)
HDL (mg/dL) ($n=1,811$)	51.7	51.6 (0.3)
TG (mg/dL) ($n=1,813$)	87.0	86.2 (1.4)
LDL (mg/dL) ($n=1,811$)	96.4	96.3 (0.6)
HbA1c (%) ($n=1,841$)	5.4	5.3 (0.008)
MS ($n=1,810$)	77	4.2 (3.2–5.2)
Central obesity ($n=2,059$)	203	10.0 (8.4–11.5)

[a]Numbers are reported for categorical variables and means for continuous variables. [b]Weighted percentage (95% confidence interval) or weighted mean (standard error)

Ht height, *Wt* weight, *BMI* body mass index, *WC* waist circumference, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL* high-density lipoprotein, *TG* triglycerides, *LDL* low-density lipoprotein, *HbA1c* hemoglobin A1C, *MS* metabolic syndrome

Statistical analyses

Weighted values were used for the demographic and clinical characteristics of the study population, as recommended by the KNHANES. Continuous variables were presented as weighted mean and standard error, whereas categorical variables were expressed as weighted percentages with a 95% confidence interval.

The prevalence of high BP according to various BP classifications was compared using the weighted McNemar's test of symmetry. When comparing upwardly reclassified/high individuals with consistently normotensive individuals, a propensity score analysis was used to match age, sex, and height (percentile) to minimize their potential influence on BP values. Unweighted paired analyses were used for the comparisons. Continuous variables were presented as mean and standard deviation, with differences being assessed through the paired t-test or Wilcoxon signed-rank test based on normal distribution confirmation. Categorical values were expressed as percentages, with comparisons among groups being performed by using McNemar's test.

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA), with P-values < 0.05 considered statistically significant.

Results

Characteristics of the study participants

This study examined 2,060 participants aged 10–18 years. Participants had a mean age of 14.3 years, with 52.1% being male (47.9%, female). Overweight and obesity rates were 9.9% and 12.5%, respectively, and central obesity was present in 10%. The prevalence of MS was 4.2%. Additional demographic and clinical characteristics of the patients are shown in Table 1.

Prevalence of BP elevation

The prevalence rates of elevated BP/high normal, stage 1 HTN, and stage 2 HTN were 9.4%, 9.3%, and 0.8%, respectively, using the AAP; 6.3%, 3.9%, and 0.4%, respectively, using the ESH; and 9.3%, 9.4%, and 0.8%, respectively, using the KRC (Fig. 1A) (Supplementary Tables 5–7). High BP, as classified by the AAP and KRC, was more prevalent in boys (Fig. 1B). Overweight and obese participants exhibited a higher prevalence of high BP across all criteria compared to participants with normal weight (Fig. 1C).

When data were analyzed according to the three age groups, stage 1 HTN was more prevalent in the < 13-year-old and 13–16-year-old groups according to both the AAP and KRC compared to the ESH. In the ≥ 16-year-old

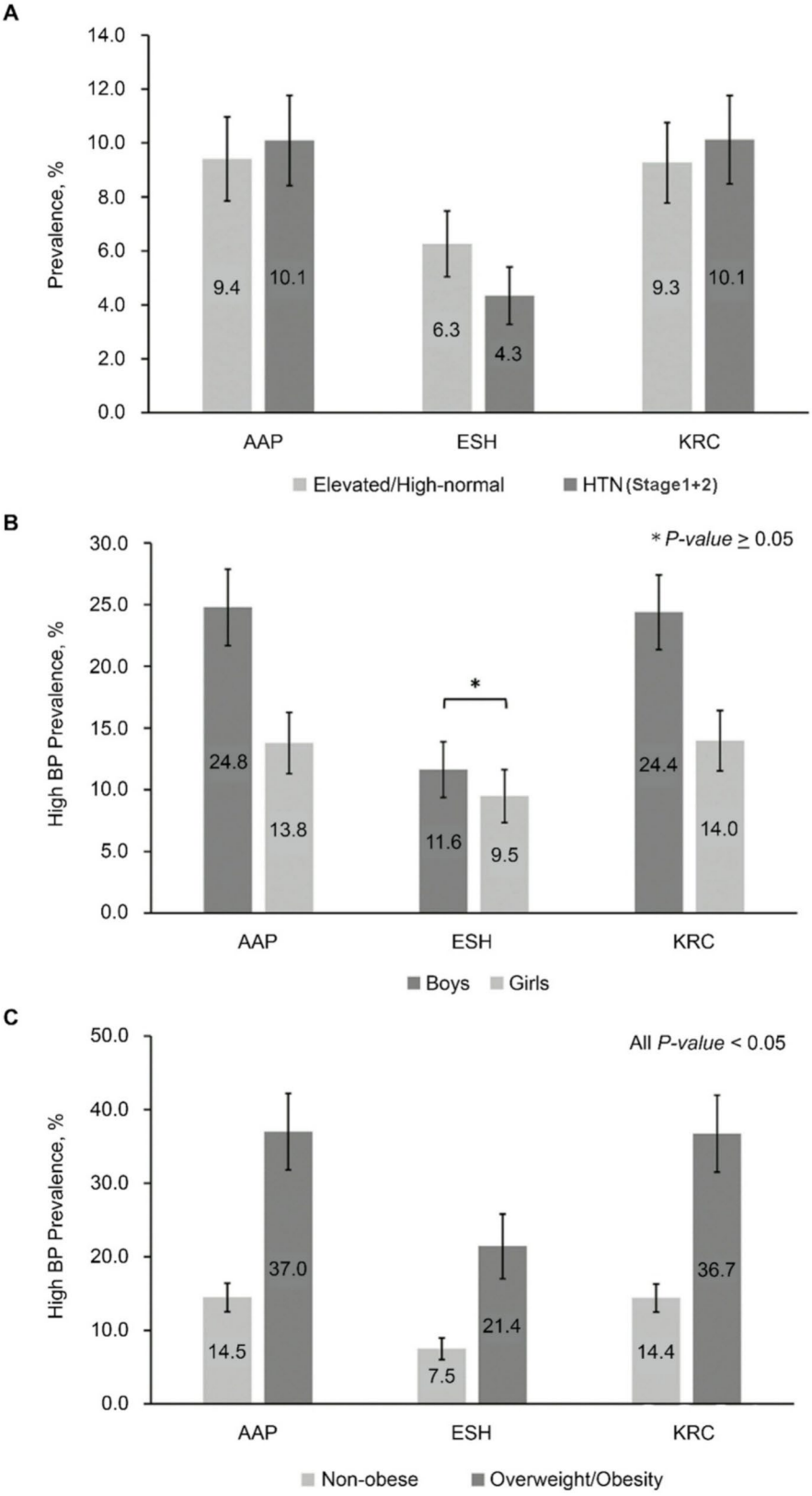

Fig. 1 Prevalence of BP elevation in Korean children according to (**A**) each guideline, (**B**) sex, (**C**) obesity, weighted. *AAP* American Academy of Pediatrics, *BP* blood pressure, *ESH* European Society for Hypertension, *HTN* hypertension, *KRC* Korea Regional Blood Pressure Classification

group, all BP stages were more prevalent according to the AAP and KRC groups than the ESH group (Fig. 2). No differences in prevalence were observed between the AAP and KRC groups.

CV risk factor distribution differences

AAP vs. ESH

The AAP reclassified 156 children as having high BP (AAP upwardly reclassified), whereas the ESH reclassified only 11 children (ESH upwardly reclassified). Compared to their matched normotensive counterparts, the AAP upwardly reclassified group showed significant differences in adiposity and metabolic profiles(higher weight z-score, higher BMI z-score, higher waist circumference, higher TC, higher LDL, more central obesity and MS), while the ESH upwardly reclassified group only had lower HDL levels (Table 2).

AAP vs. KRC

A total of 16 children were reclassified as having high BP by the AAP (AAP upwardly high), while 11 were reclassified by the KRC (KRC upwardly high). No significant differences were observed between the upwardly high group and their normotensive counterparts. Although not statistically significant, the KRC demonstrated a tendency to classify more non-obese children (lower weight z-scores, lower BMI z-scores, and lower waist circumferences) as having high BP compared to the AAP (Table 3).

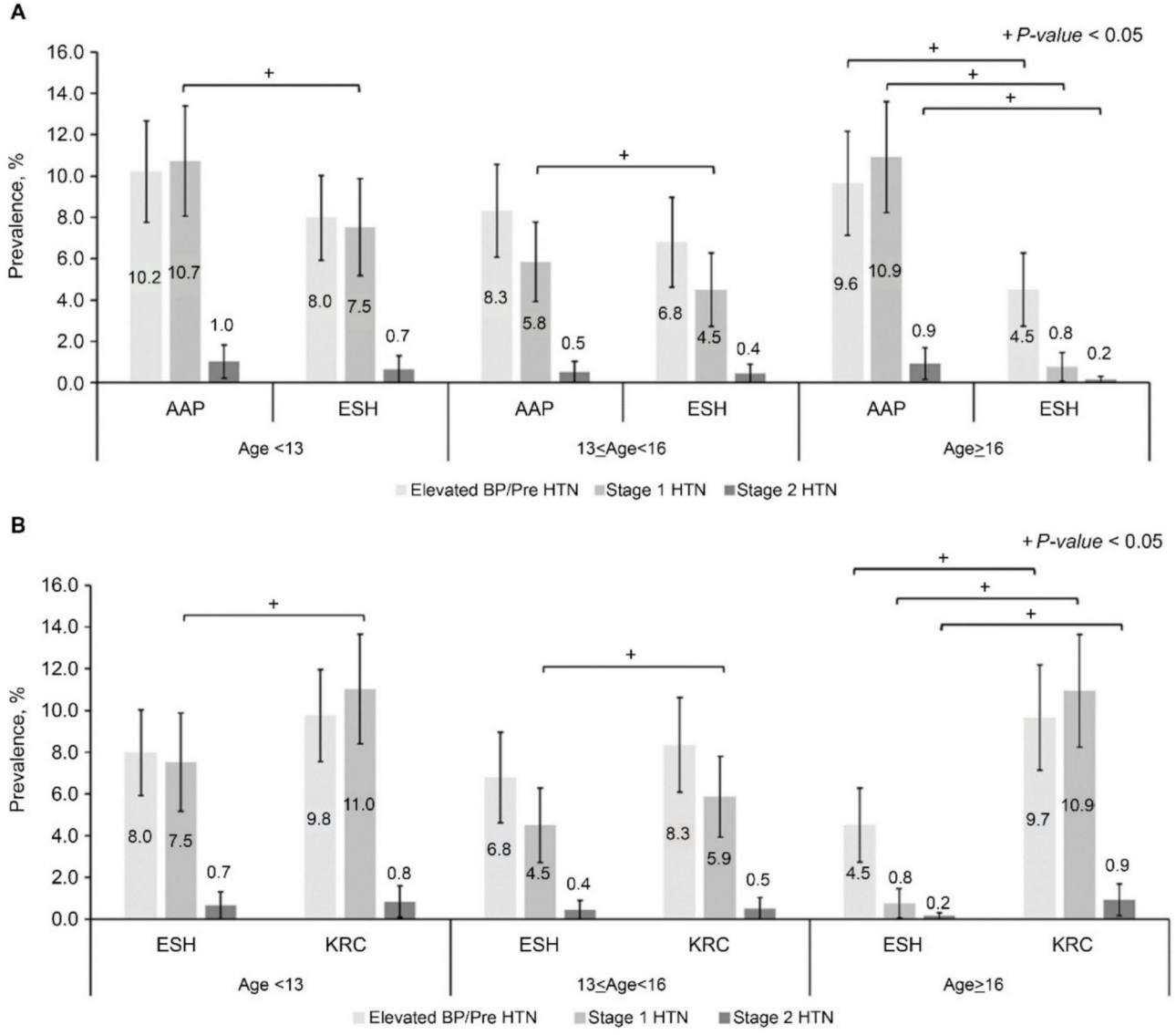

Fig. 2 Difference in prevalence of high BP according to age group as classified by (**A**) AAP versus ESH and (**B**) ESH versus KRC. All weighted. *AAP* American Academy of Pediatrics, *BP* blood pressure, *ESH* European Society for Hypertension, *HTN* hypertension, *KRC* Korea Regional Blood Pressure Classification

Table 2 AAP upwardly reclassified and ESH upwardly reclassified vs. age-, sex-, and height-matched consistently normotensive participants, unweighted

Characteristic	Normotensive (*n* = 156)	AAP upwardly reclassification (*n* = 156)	*P*-value	Normotensive (*n* = 11)	ESH upwardly reclassification (*n* = 11)	*P*-value
Age, year	15.2 ± 2.6	15.2 ± 2.6	.	13.9 ± 0.8	13.9 ± 0.8	.
Sex, male	119 (76.3)	119 (76.3)	.	5 (45.5)	5 (45.5)	.
Overweight /obesity	30 (19.2)	58 (37.2)	0.0005	2 (18.2)	4 (36.4)	0.6250
Wt z-score	0.2 ± 1.2	0.8 ± 1.4	< 0.0001	-0.09 ± 1.1	0.006 ± 1.1	0.8219
BMI z-score	-0.05 ± 1.2	0.7 ± 1.6	< 0.0001	-0.1 ± 1.5	0.04 ± 1.5	0.7937
WC (cm)	71.7 ± 9.2	76.7 ± 13.0	< 0.0001	67.2 ± 7.2	67.2 ± 5.1	0.9826
TC (mg/dL)	159.8 ± 24.9	166.3 ± 28.6	0.0317	162.2 ± 15.8	159.2 ± 27.3	0.3779
HDL (mg/dL)	49.9 ± 9.4	49.3 ± 8.7	0.5502	51.6 ± 7.3	46.3 ± 8.7	0.0347
TG (mg/dL)	83.6 ± 50.3	95.6 ± 51.4	0.0102	83.6 ± 39.7	98.9 ± 47.7	0.1739
HbA1c (%)	5.4 ± 0.2	5.3 ± 0.2	0.6541	5.3 ± 0.3	5.3 ± 0.2	0.9232
LDL (mg/dL)	93.5 ± 22.0	98.9 ± 25.1	0.1102	93.8 ± 17.6	93.1 ± 21.8	0.5195
High TC	12 (7.7)	17 (14.7)	0.3359	1 (9.1)	2 (18.2)	1
Low HDL	19 (12.2)	23 (14.7)	0.5164	1 (9.1)	4 (3.4)	0.25
High LDL	11 (7.1)	13 (8.3)	0.8318	1 (9.1)	1 (9.1)	1
High TG	19 (12.2)	29 (18.6)	0.1228	2 (18.2)	3 (27.3)	1
High HbA1c	11 (7.1)	19 (12.2)	0.1441	1 (9.1)	2 (18.2)	1
High FBG	14 (9.0)	14 (9.0)	1	1 (9.1)	2 (18.2)	1
MS	4 (2.6)	17 (10.9)	0.0044	1 (9.1)	0	1
Central obesity	11 (7.1)	36 (23.1)	< 0.0001	1 (9.1)	0	1

Data are presented as the mean ± standard deviation or number (%)

AAP American Academy of Pediatrics, *ESH* European Society for Hypertension, *Wt* weight, *BMI* body mass index, *WC* waist circumference, *TC* Total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *HbA1c* hemoglobin A1C, *FBG* fasting blood glucose, *MS* metabolic syndrome

Table 3 AAP upwardly high and KRC upwardly high vs. age-, sex-, and height-matched consistently normotensive participants, unweighted

Characteristic	Normotensive (*n* = 16)	AAP upwardly high (*n* = 16)	*P*-value	Normotensive (*n* = 11)	KRC upwardly high (*n* = 11)	*P*-value
Age, years	10.8 ± 0.7	10.8 ± 0.7	.	10.3 ± 0.6	10.3 ± 0.6	.
Sex, male	13 (81.3)	13 (81.3)	.	7 (63.6)	7 (63.6)	.
Overweight /obesity	2 (12.5)	4 (25.0)	0.5	3 (27.3)	2 (18.2)	1
Wt z-score	0.3 ± 1.2	0.4 ± 1.1	0.4394	0.9 ± 1.1	0.4 ± 1.1	0.1522
BMI z-score	-0.01 ± 1.3	0.2 ± 1.1	0.4123	0.5 ± 1.4	-0.1 ± 1.2	0.1425
WC (cm)	65.1 ± 9.1	66.6 ± 10.0	0.4586	67.7 ± 10.5	61.8 ± 6.8	0.0536
TC (mg/dL)	155.3 ± 19.6	167.6 ± 28.0	0.1744	164.2 ± 23.1	180.0 ± 23.7	0.1242
HDL (mg/dL)	46.6 ± 8.3	52.7 ± 10.6	0.1272	51.1 ± 10.9	55.9 ± 10.1	0.2406
TG (mg/dL)	93.7 ± 30.1	88.7 ± 46.4	0.2363	86.6 ± 42.0	75.2 ± 38.4	0.5284
HbA1c (%)	5.4 ± 0.2	5.4 ± 0.2	0.4904	5.4 ± 0.2	5.3 ± 0.3	0.5656
LDL (mg/dL)	90.0 ± 22.5	98.0 ± 27.5	0.3642	95.8 ± 23.9	109.1 ± 19.4	0.1635
High TC	0	1 (6.25)	1	0	3 (27.3)	0.25
Low HDL	3 (18.8)	2 (12.5)	1	1 (9.1)	1 (9.1)	1
High LDL	0	2 (12.5)	0.5	0	2 (18.2)	0.5
High TG	1 (6.3)	2 (12.5)	1	1 (9.1)	1 (9.1)	1
High HbA1c	0	4 (25.0)	0.125	3 (27.3)	1 (9.1)	0.5
High FBG	2 (12.5)	1 (6.25)	1	0	0	.
MS	1 (6.3)	1 (6.3)	.	1 (9.1)	0	1
Central obesity	1 (6.25)	2 (12.5)	1	2 (18.2)	0	0.5

Data are presented as the mean ± standard deviation or number (%)

AAP American Academy of Pediatrics, *KRC* Korea Regional Blood Pressure Classification, *Wt* weight, *BMI* body mass index, *WC* waist circumference, *TC* Total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *HbA1c* hemoglobin A1C, *FBG* fasting blood glucose, *MS* metabolic syndrome

Table 4 ESH upwardly high and KRC upwardly high vs. age-, sex-, and height-matched consistently normotensive participants, unweighted

Characteristic	Normotensive (*n* = 11)	ESH upwardly high (*n* = 11)	*P*-value	Normotensive (*n* = 151)	KRC upwardly reclassified (*n* = 151)	*P*-value
Age, years	13.9 ± 0.8	13.9 ± 0.8	.	15.3 ± 2.6	15.3 ± 2.6	.
Sex, male	5 (45.5)	5 (45.5)	.	113 (74.8)	113 (74.83)	.
Overweight /obesity	2 (18.2)	4 (36.4)	0.6250	29 (19.2)	56 (37.1)	0.0007
Wt z-score	-0.09 ± 1.1	0.006 ± 1.1	0.8219	0.2 ± 1.1	0.8 ± 1.4	< 0.0001
BMI z-score	-0.1 ± 1.5	0.04 ± 1.5	0.7937	-0.06 ± 1.2	0.7 ± 1.6	< 0.0001
WC (cm)	67.2 ± 7.2	67.2 ± 5.1	0.9826	71.8 ± 9.0	76.7 ± 13.2	< 0.0001
TC (mg/dL)	162.2 ± 15.8	159.2 ± 27.3	0.3779	160.5 ± 25.2	167.2 ± 28.5	0.0289
HDL (mg/dL)	51.6 ± 7.3	46.3 ± 8.7	0.0347	50.4 ± 9.5	49.4 ± 8.7	0.3224
TG (mg/dL)	83.6 ± 39.7	98.9 ± 47.7	0.1739	82.9 ± 51.2	94.8 ± 51.3	0.0107
HbA1c (%)	5.3 ± 0.3	5.3 ± 0.2	0.9232	5.3 ± 0.3	5.3 ± 0.2	0.3622
LDL (mg/dL)	93.8 ± 17.6	93.1 ± 21.8	0.5195	93.9 ± 22.0	99.7 ± 24.6	0.0287
High TC	1 (9.1)	2 (18.2)	1.0000	12 (8.0)	19 (12.6)	0.2649
Low HDL	1 (9.1)	4 (36.4)	0.2500	16 (10.6)	22 (14.6)	0.3035
High LDL	1 (9.1)	1 (9.1)	1.0000	11 (7.3)	13 (8.6)	0.8318
High TG	2 (18.2)	3 (27.3)	1.0000	19 (12.6)	28 (18.6)	0.1599
High HbA1c	1 (9.1)	2 (18.2)	1.0000	13 (8.6)	16 (10.6)	0.5637
High FBG	1 (9.1)	2 (18.2)	1.0000	12 (8.0)	13 (8.6)	1.0000
MS	1 (9.1)	0	1.0000	3 (2.0)	16 (10.6)	0.0044
Central obesity	1 (9.1)	0	1.0000	11 (7.3)	34 (22.5)	0.0003

Data is presented as the mean ± standard deviation or number (%)

AAP American Academy of Pediatrics, *KRC* Korea Regional Blood Pressure Classification, *Wt* weight, BMI body mass index, *WC* waist circumference, *TC* Total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *HbA1c* hemoglobin A1C, *FBG* fasting blood glucose, *MS* metabolic syndrome

ESH vs. KRC

Eleven children were upwardly reclassified as having high BP by the ESH (ESH upwardly high), whereas the KRC reclassified 151 (KRC upwardly reclassified). Compared to their matched normotensive counterparts, ESH upwardly high children showed significant differences in HDL levels, whereas KRC upwardly reclassified children exhibited differences in adiposity and metabolic profiles (higher weight z-score, higher BMI z-score, higher waist circumference, higher triglycerides, higher LDL, more central obesity and MS) (Table 4).

Discussion

Recently, the prevalence of HTN in Korean children has increased [31]. We sought to compare the clinical characteristics across different BP categories, aiming to propose uniform and practically applicable classification criteria tailored for Koreans. Notable differences include the AAP's utilization of a lower BP reference value, excluding obese children, and applying a static cutoff BP value at a younger age (13 years) than the ESH (16 years), with lower static cutoff values [23, 24].

Previous studies have consistently shown a higher prevalence of high BP using the AAP compared to the ESH [32–37], which is consistent with our findings. There was concern regarding a potential underdiagnosis of HTN in the AAP for youths older than 13 years, as a static cutoff BP value derived from adulthood HTN definitions was applied. Our findings support the applicability of the AAP in Korean teenagers (13–15 years); only stage 1 HTN increased, with no significant decrease. Similar trends were observed in Chinese [38] and Spanish [33] studies, suggesting that the AAP could simplify diagnostic criteria and enhance real-world HTN detection. Because BP can be influenced by race, ethnicity, and obesity, several countries have established local BP references [39–42]. Conversely, international BP reference values are derived from nationally representative cross-sectional surveys [43]. Studies comparing local and international references, as well as the inclusion or exclusion of overweight or obese children's BP data, have revealed significant discrepancies in high BP prevalence across different reference Tables [44–49]. A study conducted by Fan et al. [48] in China applied a local reference table, the AAP, the fourth report (a previous version of the BP guidelines before the AAP 2017), and international BP reference tables to a longitudinally followed cohort. This study found that high BP, as defined by the AAP and local BP references, effectively predicted subclinical CVD in adulthood [48]. From this perspective, we applied a normal-weight Korean BP reference to the AAP BP classification (KRC) to evaluate the impact of using local BP references.

We focused on the characteristics of children reclassified from normotensive to high BP groups using various criteria. Prior research has explored the clinical

differences in defining high BP using the AAP and ESH, leading to controversies regarding their ability to detect CVD risks. A study by Di Bonito et al. [34] showed that despite no prevalence difference in LVH and relative wall thickness between individuals with high BP defined by the AAP and ESH, the AAP identified more abnormal left ventricular geometries among Italian overweight or obese children. Another study by Di Bonito et al. [37] found that Italian overweight or obese children reclassified as having high BP by the AAP but normotensive by the ESH had a higher BMI, poorer metabolic profiles, and higher left ventricular mass index than consistently normotensive children.

Additionally, Kim et al. [50] reported a difference in the prevalence of BP according to the AAP and ESH in Korean youth, with a higher prevalence of high BP found using the AAP than in patients with the ESH. Those newly diagnosed with high BP by the AAP were more obese and had more severe cardiometabolic risk factors than normotensive subjects. Conversely, a study by Antolini et al. [32] reported that although the AAP increased the prevalence of high BP relative to the ESH, it did not enhance the identification of early cardiac organ damage when weight was adjusted in the analyses. Some studies compared the AAP with the fourth report. Sharma et al. [51] and Yang et al. [52] analyzed the clinical characteristics of children newly diagnosed with high BP or upwardly reclassified with a higher stage BP by the AAP, comparing them with age-, sex-, and height-matched normotensive children according to both guidelines. The upwardly reclassified children displayed adverse lipid profiles and a cluster of CV risk factors compared with matched normotensive children. These findings align with our study's comparison of the AAP and ESH criteria. This alignment may be influenced by the BP reference table used by the ESH, which is derived from the Fourth Report [24].

Children newly classified as having high BP using the KRC were primarily reclassified based on their DBP. Additionally, there was a tendency for non-obese children to be reclassified into the high-BP group when using the KRC. Increased DBP in non-obese children has been associated with insulin resistance in young adults and metabolic disorders [53]. This suggests the importance of using local reference BP tables. A comparison between KRC and ESH revealed similar patterns in the prevalence of CVD risks to the AAP and ESH comparisons. This suggests that high BP identified using the AAP and KRC criteria detects more children with CVD risk factors compared to the ESH. However, this may lead to overdiagnosis of high BP, despite increasing sensitivity for detecting CVD risk factors.

Both the AAP and ESH guidelines recommend lifestyle modifications for the initial management of high BP in children [23, 24]. We suggest that the KRC are more effective in identifying individuals at risk of CVD, contributing to the overall awareness and management of CV health in the pediatric population in Korea.

Our study had several strengths. First, we used national survey data from the KNHANES, which provides a fully representative sample of the Korean pediatric population. The use of comprehensive data strengthens the validity and applicability of the study to a broader population. Second, this study is the first to compare different BP guidelines and the impact of applying normal-weight Korean BP references in Korean youth, with the aim of determining the most reliable BP classification criteria for risk control. However, this study had certain limitations. First, the number of children reclassified according to each guideline was relatively small, potentially affecting the statistical power and generalizability of the findings. Second, the reliance on cross-sectional data from the KNHANES, which includes only one BP measurement, therefore the true prevalence of hypertension cannot be fully determined by the current study design. Third, the retrospective cross-sectional nature of this study prevents assessment of the impact of high BP, including potential TOD.

In conclusion, the KRC effectively identified Korean youth with a higher prevalence of CVD risk factors, categorizing them as having a high BP. Contrary to concerns about underdiagnosis, applying a static HTN definition starting at the age of 13 years in Korean youths did not result in an underdiagnosis of high BP. Using the KRC as a uniform and simplified set of BP criteria can reduce the likelihood of diagnosis failure and enhance early CVD risk control. Further research is warranted to investigate the longitudinal impact of the KRC use on the actual CVD outcomes in adulthood in the Korean pediatric population.

Abbreviations

AAP	American Academy of Pediatrics
BMI	Body mass index
BP	Blood Pressure
CV	Cardiovascular
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
ESH	European Society for Hypertension
HDL	High-density Lipoprotein
HTN	Hypertension
KDCA	Korea Disease Control and Prevention Agency
KNHANES	Korean National Health and Nutritional Examination Survey
KRC	Korea Regional BP Classification
LDL	Low-density lipoprotein
LVH	Left Ventricular Hypertrophy
MS	Metabolic Syndrome
TC	Total cholesterol
TG	Triglycerides
TOD	Target Organ Damage

Supplementary Information

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Supplementary Material 1

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Not Applicable.

Author contributions
JYK wrote the first draft. SP and HC contributed to conception and design of the study. All authors reviewed the manuscrip.

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Data availability
The datasets utilized in this study are available from the Korea Disease Control and Prevention Agency (KDCA) database (https://knhanes.kdca.go.kr/knhanes/rawDataDwnld/rawDataDwnld.do; accessed April 17, 2025). Registered users, including international researchers, can access and download the raw data upon membership approval.

Declarations

Ethics approval and consent to participate
The present study was approved by the Institutional Review Board (IRB) of Samsung Medical Center (IRB number 21-10-074). The informed consent was waived by IRB of Samsung Medical Center. All the data were obtained in accordance with the ethical principles for medical research involving human subjects established in the Declaration of Helsinki 1975 (revised in 2000).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Not applicable.

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