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The 2017 pediatric hypertension guidelines improve prediction of adult cardiovascular outcomes

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Abstract

To evaluate the consequences of the 2017 pediatric hypertension definitions, compared with the 2004 pediatric hypertension definitions on the prevalence of hypertension and to assess the performance of these 2 sets of guidelines in predicting adult hypertension, metabolic syndrome (MetS), and left ventricular hypertrophy (LVH). This longitudinal study consisted of 3,940 children (47% male; ages 3-18 years) who came from the Bogalusa Heart Study with 36-year follow-up since childhood. Hypertension was identified in 7% and 11% as defined in the 2004 and 2017 guidelines, respectively. The 2004 and 2017 guidelines demonstrated similar associations with adulthood hypertension, MetS, and LVH. However, the proportion of children identified as having hypertension who developed adult LVH increased from 12% when defined by the 2004 guidelines to 19% when defined by the 2017 guidelines. Overall, the 329 (8%) children who were reclassified to higher BP categories by the 2017 guidelines were more likely than their propensity score-matched normotensive counterparts to develop hypertension, MetS, and LVH in later life, whereas 38 (1%) children who were reclassified to lower BP categories by the 2017 guidelines had similar cardiometabolic outcomes to their propensity score-matched normotensive counterparts. Hence, children who were reclassified to higher BP categories based on 2017 guidelines were at increased risk of developing hypertension, MetS, and LVH in later life. The 2017 guidelines identified a group of children with adverse metabolic profile and cardiometabolic outcomes, whose cardiovascular risk appeared to be underestimated using the 2004 guidelines.

Keywords

Blood pressure; child; hypertension; left ventricular hypertrophy; longitudinal studies

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Disclosures

The authors declare no conflict of interests.

Introduction

In August 2017, a new guideline for the diagnosis and management of elevated blood pressure (BP) in children was jointly published by the American Academy of Pediatrics (AAP) and endorsed by the American Heart Association (AHA).[1, 2] This guideline is an update from the fourth report of the National Institutes of Health's National Heart, Lung, and Blood Institute (NIH/NHLBI) published in 2004.[3] Studies linking BP levels in childhood with heightened risk for subsequent adverse cardiovascular outcomes are required to better appraise the value of these new BP thresholds. Furthermore, before these new BP thresholds are adopted as the basis for identifying children at high-risk of cardiovascular disease (CVD), it is necessary to answer the following crucial questions: Do the additional children whose BP levels were reclassified upward (those who are newly defined as having elevated BP or new-onset hypertension or are assigned a more advanced stage under the 2017 AAP guidelines) indeed have adverse cardiometabolic outcomes? What are the cardiometabolic outcomes of the children whose BP is newly assigned to a lower level by the 2017 AAP guidelines compared to the 2004 NIH/NHLBI guidelines?

The aim of this study was therefore to directly compare the ability of the 2004 NIH/NHLBI guidelines and the new 2017 AAP guidelines to predict cardiometabolic outcomes including hypertension, metabolic syndrome (MetS), and subclinical CVD later in life with the use of data from the longitudinal cohort of the Bogalusa Heart Study (BHS). As a secondary aim, we evaluated CVD risk profile and cardiometabolic outcomes among children whose BP levels were reclassified upward and whose BP levels were reclassified downward under the 2017 guidelines compared with the 2004 NIH/NHLBI report.

Methods

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Cohort

The BHS is a series of long-term studies begun in 1973 focusing on understanding the early natural history of CVD since childhood.[4] Between 1973 and 2016, 9 cross-sectional surveys of children aged 3 to 18 years and 11 surveys of adults aged 19 to 58 years, who had been previously examined as children were conducted in the semirural biracial (65% white and 35% black) community of Bogalusa, Louisiana. This panel design of repeated cross-sectional examinations conducted approximately every 3 to 4 years, resulted in serial observations from childhood to adulthood. A total of 3,940 children (2,523 whites and 1,417 blacks; 47% male; ages 3-18 years at baseline) had been examined for BP at least once in childhood (baseline) and at least once in adulthood (follow-up) were included in the analysis exploring which guidelines better predicted progression to adulthood hypertension. Among those participants, 3,437 adults (45% men; ages 19-57 years at follow up) had measures of waist circumference (WC), systolic/diastolic BP, total cholesterol (TC), triglyceride (TG), low- and high-density lipoprotein cholesterol (LDL-C and HDL-C), and fasting plasma glucose (FPG) and thus could be included in the analysis exploring which guidelines better predicted the development of MetS in adulthood. Of the 3,940 children, 1,760 (44% male;

ages 24-57 years at follow up) had adult echocardiography conducted between 2000 and 2016 to measure left ventricular hypertrophy (LVH) and were included in the analysis exploring which guidelines better predicted progression to LVH. There was no difference in the baseline characteristics between children who had and did not have adult echocardiography measurements (Table S1)

Written informed consent was obtained from parents or guardians in childhood and from the participants themselves in adulthood. Study protocols were approved by the Institutional Review Board of the Tulane University Health Sciences Center.

Clinical measurements

Standardized protocols were followed by trained and certified personnel across all surveys. Participants were instructed to fast for 12 hours before the screening. For each participant, replicate measurements of height and weight were obtained, and the mean values were used for analysis. BMI was calculated as weight in kilograms divided by height in meters squared. WC in adults was measured midway between the rib cage and the superior border of the iliac crest twice, to the nearest 0.1 cm by a non-stretchable tape, and the mean value was used in analysis. BP was measured between 8:00 AM and 10:00 AM on the right arm with appropriate cuff in a relaxed sitting position by 2 trained technicians (triplicate each), using calibrated mercury sphygmomanometers. The 6 readings were averaged. For both children and adults, the first Korotkoff phase was used for systolic BP; The fifth Korotkoff (K5) phase was used for diastolic BP. Diastolic BP at the fourth Korotkoff (K4) phase was also recorded for all children. For children with the K5 being very low (<20 mm Hg), the K4 was used as diastolic BP.[3]

Biochemical laboratory measurements

Between 1973 and 1986, TC and TG were determined with Technicon Auto Analyzer II (Technicon Instrument Corp, Tarrytown, NY) according to the laboratory manual of the Lipid Research Clinics Program. From 1987, these variables were measured using an Abbott VP instrument (Abbott Laboratories, Abbott Park, Ill) by enzymatic procedures.[5, 6] Both chemical and enzymatic procedures met the performance requirements of the Lipid Standardization Program of the Centers for Disease Control and Prevention (CDC). Measurements on CDC-assigned quality control samples showed no consistent bias over time within or between surveys. Serum lipoprotein cholesterols were analyzed by using a combination of heparin-calcium precipitation and agar-agarose gel electrophoresis procedures.[7] Between 1978 and 1991, FPG was determined with a glucose oxidase method using a Beckman glucose analyzer (Beckman Instruments, Fullerton, CA). Since 1992, FPG has been measured enzymatically as part of a multichemistry profile.

Echocardiography

Left ventricular mass (LVM) was measured by 2-dimensional M-mode echocardiography with 2.25- and 3.5-MHz transducers following American Society of Echocardiography recommendations.[8] Parasternal long- and short-axis views were used for measuring LV end-diastolic and end-systolic measurements in duplicate, and the mean was calculated. LV mass was calculated from a necropsy-validated formula on the basis of a thick-wall prolate

ellipsoidal geometry.[9] The index of LVM to height$^{2.7}$ (g/m $^{2.7}$) (LVMI) was used to adjust for body size.

Statistical Analysis

For both the 2004 NIH/NHLBI[3] and the 2017 AAP references,[1] age-, sex-, and height-specific systolic/diastolic BP percentiles were calculated. We assessed elevated BP and hypertension status in children per Table S2. For individuals having more than one visit in childhood, children were classified as normotensives if BP values in all visits were below the cutoffs of 2017 AAP guidelines. Children were classified as having elevated BP, stage 1, or stage 2 hypertension if BP values in at least one childhood visit was above the cutoffs of the 2017 guidelines. The same process was repeated for the 2004 NIH/NHLBI guidelines. We assessed status of lipoprotein variables in children according to the National Cholesterol Education Program (NCEP)[10] (Table S3). In adulthood, participants were classified as having hypertension if they had systolic BP ≥ 130 mmHg, diastolic BP ≥ 80 mmHg, and/or with self-reported treatment of hypertension with antihypertensive medication according to the 2017 ACC/AHA guidelines on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guidelines.[11] We also performed a sensitivity analysis using adult hypertension definition according to the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC7).[12] MetS was defined according to the consensus criteria in 2009[13] as the presence of three or more of the following criteria: elevated WC; TG ≥ 150 mg/dl; HDL-C <40 mg/dl in men and < 50 mg/dl in women; BP ≥ 130/85 mmHg or on antihypertensive drug treatment in a patient with a history of hypertension; or FPG ≥ 100 mg/dl. LVH was defined as LVMI >46.7 g/m$^{2.7}$ in women and >49.2 g/m$^{2.7}$ in men.[14]

All statistical analyses were performed with SAS version 9.2 (SAS Institute Inc., Cary, North Carolina). Age- and sex-specific z scores were calculated for childhood height using Lambda Mu Sigma (LMS) tables from the CDC.[15] These height Z scores were then converted to age- and sex-specific height percentiles. The differences in baseline and follow-up variables between groups were tested using generalized linear models (for continuous) and χ^2 or Fisher exact tests (for categorical). The kappa (κ) statistic was calculated to assess agreement in BP categorization as defined in the 2017 AAP guidelines and the 2004 NIH/NHLBI guidelines.

Poisson regression models with robust errors variance were used to examine the ability of the 2017 AAP guidelines and the 2004 NIH/NHLBI guidelines in predicting adult hypertension, MetS, and LVH, with adjustment for age, sex, race, childhood BMI, and length of follow-up. For individuals who participated in multiple baseline or follow-up surveys, we used those measures that provided the longest time period between baseline and follow-up. We also used receiver operating characteristic (ROC) curve analysis to determine the performance of these two guidelines in predicting adult hypertension, MetS, and LVH.

Children whose BP readings were reclassified to a higher level under the 2017 guidelines in comparison with the 2004 NIH/NHLBI guidelines were considered “reclassified upward” and treated as cases. One-to-one propensity score matching by age, sex, height percentile, and length of follow-up resulted in the inclusion of 329 pair of participants (cases and

children with normal BP based on both sets of guidelines. Continuous variables of these two groups were analyzed with the paired-sample Student t test. Differences for categorical variables were compared using McNemar's test. Standardized differences of matched pairs were also used to assess the balance of the covariates that were included in the propensity score model. Conditional logistical regression models were used to examine the relationship between reclassifications (case status) and development of adult health outcomes including hypertension, MetS, and LVH. The process was repeated for the children whose BP levels were reclassified downward under the 2017 guidelines compared with the 2004 NIH/NHLBI guidelines. Significance was accepted at a two-tailed $P < 0.05$.

Results

Characteristics of participants with normal BP, elevated BP and hypertension as classified by the two sets of guidelines are presented in Table 1. Overall, children with elevated BP or hypertension were more likely to be boys, black, and obese as compared with normotensive children. Likewise, more of those individuals classified as having elevated BP or hypertension in childhood went on to develop hypertension, MetS, and LVH in adulthood.

Using the 2017 AAP BP tables, the mean systolic BP percentile of all participants was higher (50) compared with the 2004 NIH/NHLBI report (45). The proportions of children with stages 1 or 2 hypertension were significantly higher when classified under the 2017 definition (10% [381] stage 1 and 1% [51] stage 2 hypertension) compared with the 2004 definition (6% [246] stage 1 and 0.5% [19] stage 2 hypertension).

There were 1117, 715, and 362 incident cases of adulthood hypertension, MetS, and LVH, respectively, during a mean 25 years (range, 5-43 years), 27 years (range, 5–43 years), and 36 years (range, 17–43 years) of follow-up, respectively. Because of the infrequency of stage 1 and stage 2 hypertension, we collapsed these 2 group into a single hypertension group. Children with elevated BP (previously called prehypertension in the 2004 Report) or hypertension under either definition were at higher risk for developing adult hypertension, MetS, and LVH compared with normotensive children (Table 2). Magnitude of the relative risk estimates and 95% confidence intervals for these outcomes were similar for the 2004 and 2017 guidelines.

Overall, 329 children were reclassified upward under the 2017 guidelines compared with the 2004 report (Table 3). Of these, 109 children with normal BP as defined in the 2004 report were reclassified to elevated BP (n=108) or stage 1 hypertension (n=1) as defined in the 2017 guidelines. Another 192 children who were categorized as prehypertensive by the 2004 guidelines were reclassified to stage 1 (n = 188) and stage 2 (n = 4) hypertension by the 2017 guidelines; while 28 children with stage 1 hypertension by the 2004 report were reclassified as having stage 2 hypertension by the 2017 guidelines. Among the 38 children who were reclassified downward, 12 went from prehypertension according to the 2014 guidelines to normal BP according to the 2017 guidelines, and 26 went from stage 1 hypertension under the 2004 guidelines to elevated BP under the 2017 guidelines. The κ coefficient between the 2004 and 2017 pediatric BP classification was 0.83 (95% CI, 0.82-0.85). The agreement between these two sets of guidelines was 0.82 (95% CI,

0.80-0.84) in boys, 0.85 (95% CI, 0.82-0.87) in girls. Among white children the kappa value was 0.82 (95% CI, 0.80-0.84) and among black children, 0.85 (95% CI, 0.83-0.87).

To better characterize the CVD risk profile and cardiometabolic outcomes, the 329 children whose BP levels were reclassified upward under the 2017 guidelines were compared with propensity score-matched children who were classified as normotensive by both sets of guidelines. Covariates that were included in the propensity score model were balanced between the two groups (Table S4). Those children with reclassified upward BP levels had significantly higher baseline BMI, TC, lower follow-up HDL-C, and higher LVMI (all $P<0.05$) (Table 4). In addition, they experienced a higher prevalence of hypertension, MetS, and LVH at follow-up. For the outcome of adult hypertension of the propensity score-matched pairs, the odds ratio (95% CI) was 2.37 (1.67–3.35) for children whose BP levels were reclassified upward as compared with normotensive children (Table 5). For the outcome of adult MetS and LVH, the corresponding figures were 1.50 (1.07–2.31) and 2.18 (1.23–3.88), respectively. Since risks of cardiometabolic outcomes might be contributed by increased BMI and TC levels, which clustered with increased BP, we further compared the cardiometabolic outcomes of propensity score-matched pairs after adjusting for BMI and TC. The risks of adult hypertension MetS, and LVH for the children whose BP values were reclassified upward slightly changed but remained still statistically significant (Table 5). Additionally, we compared the cardiometabolic outcomes of propensity score-matched pairs after excluding overweight and obese children (Table 5). One-to-one propensity score matching by age, sex, height percentile, BMI, TC, and length of follow-up resulted in the inclusion of 197 pair of participants (children whose BP readings were reclassified upward and children with normal BP). Compared with normotensive children, those with BP readings reclassified upward experienced higher risk of adult hypertension and MetS. There was no significant difference in risk of LVH (Table S5).

CVD risk profile and cardiometabolic outcomes among the 38 children whose BP levels were reclassified downward under the 2017 guidelines were also compared with propensity score-matched controls. The groups differed in none of any anthropometric and biochemical measures (Table S6). These children whose BP values were reclassified downward did not experience increased risks for adult hypertension, MetS or LVH (Table S7).

The area under the ROC curves for detection of adult hypertension, MetS, and LVH increased incrementally under the 2017 guidelines even though the increases are not statistically significant (Table S8). It is important to note that childhood hypertension assessed by 2004 and 2017 guidelines preceded LVH in 12% (44), and 19% (67) of incident cases of LVH, respectively (Table S9). Of the 98 children who were reclassified from prehypertension under the 2004 guidelines to hypertension under the 2017 guidelines, 26 (27%) developed LVH in adulthood. For the outcomes of adulthood hypertension and MetS, similar patterns were noted (Tables S10-11).

The optimal cut-points for systolic/diastolic BP values in different age groups based on associations with adult hypertension were presented in Table S12.

In the sensitivity analysis, the results were similar when adult hypertension was defined by the JNC7 criteria (Tables S13-14).

Discussion

In the current study, despite the similar strengths of associations and overall predictive performance, as compared with the 2004 guidelines, the 2017 guidelines detected more children with hypertension, and more of these hypertensive children developed cardiometabolic outcomes including hypertension, MetS, and LVH in adulthood. For example, among those who went on to develop LVH in adulthood, the proportion with childhood hypertension increased from 12% under the 2004 guidelines to 19% under the 2017 guidelines. Children reclassified to more advanced levels of abnormal BP based on the 2017 guidelines had more unfavorable CVD risk characteristics and experienced higher risks for adult hypertension, MetS, and LVH compared with their propensity score-matched normotensive children. Our results also show that those children reclassified to lower levels, have similar anthropometric and biochemical characteristics and cardiometabolic outcomes to normotensive children. These findings have important health implications and support that the new BP thresholds are justifiable.

BP thresholds for elevated BP and hypertension in childhood are primarily based on the statistical distribution of BP levels rather than linking childhood BP levels to CVD outcomes in later life.[16, 17] The 2017 guidelines make a prominent change in childhood BP categorization, the establishment of absolute BP thresholds that were the same cut points used in the new 2017 adult guidelines on BP classification[18] for defining elevated BP, stage 1, and stage 2 hypertension for children ≥ 13 years old. The choice of adult cut points is primarily based on the predictive value of BP for CVD outcomes.[19] However, to our knowledge, there are no other studies to date assessing the ability of the 2017 pediatric hypertension categories to predict subclinical CVD outcomes in adulthood. The current study is unique in that it followed individuals from childhood to adulthood and assessed the performance of BP categories according to 2017 guidelines in prediction of adult outcomes of adult hypertension, MetS, and LVH.

In our study, the 2017 guidelines identified a group of children who were more likely than their propensity score-matched normotensive pairs to be obese, and hypercholesterolemic (elevated TC) at their baseline examination. It is known that childhood obesity is associated with an unfavorable cardiometabolic profile [20] and is a predictor for future CVD incidence and all-cause mortality.[21] Like obesity, childhood elevated TC may have its own effect on BP or reflect a common etiology associated with increased BP levels or the individual's lifestyle.[22] A recent cross-sectional study showed that those children reclassified upward under the 2017 guidelines were more obese and had higher LDL-C levels compared with normotensive children.[23] In the current longitudinal study, we observed that the children who were reclassified upward were at increased risk of developing adult hypertension, MetS, and LVH even after adjusting for BMI and TC. Furthermore, in normal weight children, those with BP readings reclassified upward still experienced higher risks of adult hypertension and MetS. Taken together, it seems that the 2017 guidelines identify a group of high-risk children with cardiometabolic outcomes, whose CVD risk were underestimated

when using the 2004 guidelines. It is recommended that using BP levels in conjunction with other CVD risk factors to guide the recommendation to initiate treatment has the potential to prevent more CVD events and may be cost-effective [18]. Given that childhood BP, BMI, and TC were key contributors to CVD health [24], the 2017 guideline may contribute to risk stratification in clinical decision making for children whose BP levels were reclassified upward and encourage more involved diagnostic evaluations and lifestyle modification. However, children whose BP levels were reclassified upward based on 2017 guidelines might not develop CVD events. Longitudinal studies of CVD morbidity and mortality will ultimately be needed to precisely evaluate the effect of the 2017 guidelines on CVD outcomes, which will further refine the BP guidelines for children.

Our study also showed that implementing the 2017 guidelines may reclassify some children to lower BP categories (38, 1%) who would otherwise be assigned to higher categories by the 2004 criteria. A notable finding from our study was the lack of significant differences in cardiometabolic outcome between the children who were reclassified downward under the 2017 guidelines and those propensity score-matched normotensive children. On the basis of these findings, it would appear that the children who were reclassified downward may not require additional evaluation.

The strength of our study includes a well-characterized cohort with extended follow-up and with echocardiography examination, BP readings measured by the criterion standard of auscultation, left-ventricular mass assessed according to recommendations in both sets of guidelines, and detailed anthropometric and laboratory measures from childhood to adulthood. In addition, this study is one of the first to explore cardiometabolic outcomes among children whose BP levels were reclassified under the 2017 guidelines.

Limitations of the present study require careful consideration. First, it may be underpowered to properly evaluate the differences in metabolic profile and cardiometabolic outcomes between children who were reclassified to a different BP category compared with those normotensive children because of insufficient numbers. For instance, the OR for adult hypertension was 1.62 (0.61-4.32) for those “down classified” – it was not significant but this may be due to small numbers (n=38). Second, given the community-based sample, extrapolating results to the whole of the US should be cautious. Finally, major CVD events in adulthood, such as coronary heart disease and stroke were not available in the data. Nevertheless, subclinical outcomes such as LVH and MetS, and cardiovascular diseases like hypertension are strongly predictive of later life major CVD events.

Perspectives

We demonstrated that the 2017 guidelines increased hypertension prevalence as a result of reclassification to higher BP categories. Although the 2004 and 2017 guidelines were similar in overall ability to predict adult hypertension, MetS, and LVH, using the 2017 guidelines improved the sensitivity of childhood hypertension in predicting future development of LVH in adulthood. Implementing the 2017 guidelines would identify a group of children who were reclassified upward with newly diagnosed elevated BP or a worsening stage of

hypertension with adverse metabolic profile and increased risks of progression to adult hypertension, MetS, and LVH.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Novelty and Significance

What Is New?

To our knowledge, this is the first study to explore the question: Do the additional children whose blood pressure (BP) levels were reclassified upward under the 2017 pediatric hypertension guidelines compared with the 2004 pediatric hypertension definitions indeed have adverse cardiometabolic outcomes?

What Is Relevant?

Children who were reclassified to higher BP categories by the 2017 guidelines were more likely than their propensity score-matched normotensive counterparts to develop hypertension, MetS, and LVH in later life, whereas children who were reclassified to lower BP categories by the 2017 guidelines had similar cardiometabolic outcomes to their matched normotensive counterparts. These findings have important health implications.

Summary

The 2017 guidelines identified a group of children with adverse metabolic profile and cardiometabolic outcomes, whose cardiovascular risk appeared to be underestimated using the 2004 guidelines.

Table 1.

Baseline and follow-up characteristics of study participants according to baseline blood pressure categories

Variable	Normotension by the 2004 and 2017 criteria (Group 1, n=2812)	Elevated BP by the 2004 or 2017 criterion (Group 2, n=886)	Hypertension by the 2004 or 2017 criterion (Group 3, n=242)
Whites, n (%)	67 *†	59 ‡	49
Males, n (%)	42 †	60 ‡	47
	Baseline		
Age (years)	10±3 †	10±3 ‡	9±3
Height percentile	47±28 *†	52±27 ‡	58±28
BMI (kg/m^2)	17±3 *†	18±4 ‡	19±5
SBP (mmHg)	98±9 *†	105±10 ‡	114±13
DBP (mmHg)	51±9 *†	54±10 ‡	56±11
TC (mg/dl)	162±28	165±30	163±28
TG (mg/dl)	67±32	70±34	71±44
LDL-C (mg/dl)	89±23	90±25	90±22
HDL-C (mg/dl)	66±21	67±22	65±23
FPG (mmol/l)	4.6±0.7	4.7±0.5	4.7±0.5
	Follow-up		
Age (years)	35±12	36±12	34±12
BMI (kg/m^2)	28±7 *†	29±7 ‡	32±9
WC (cm)	89±18 *†	94±18 ‡	97±21
SBP (mmHg)	115±14 *†	123±15 ‡	126±17
DBP (mmHg)	71±11 *†	75±13 ‡	76±14
TC (mg/dl)	184±38	187±41	182±40
TG (mg/dl)	117±108 *	128±94 ‡	106±61
LDL-C (mg/dl)	113±33	116±37	112±34
HDL-C (mg/dl)	51±16 *	49±16 ‡	51±17
FPG (mmol/l)	5.1±1.7 *†	5.4±2	5.5±2
LVMI (g/m $^{2.7}$)	38±11 *†	42±15 ‡	47±18
Hypertension (%)	23 *†	41	47
MetS (%)	19 *†	28	28
LVH (%)	16 *†	26 ‡	37

Values are mean±SDs.

BMI, Body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglycerides; LDL-C, low density lipoprotein cholesterol; HDL-C high density lipoprotein cholesterol; FPG, fasting plasma glucose, WC, waist circumference; LVMI, left ventricular mass index; MetS, metabolic syndrome; LVH, left ventricular hypertrophy

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[*] P value for difference between group1 and group 2

[†] P value for difference between group1 and group 3

[‡] P value for difference between group2 and group 3

Table 2.

Relative risks (RR) and 95% confidence intervals (CI) for adult hypertension, metabolic syndrome (MetS), and left ventricular hypertrophy (LVH) according to childhood blood pressure categories by the 2004 or 2017 definitions

Health Outcome	2004 NIH/NHLBI guidelines			2017 American Academy of Pediatrics guidelines		
	RR	95% CI	P Value	RR	95% CI	P Value
Childhood prehypertension or elevated blood pressure						
Adult hypertension	1.49	1.34-1.65	<0.001	1.45	1.30-1.61	<0.001
Adult MetS	1.29	1.12-1.50	0.0004	1.25	1.07-1.45	0.0049
Adult LVH	1.30	1.05-1.60	0.0151	1.31	1.05-1.63	0.0155
Childhood hypertension						
Adult hypertension	1.71	1.48-1.98	<0.001	1.66	1.47-1.87	<0.001
Adult MetS	1.30	1.04-1.62	0.0188	1.36	1.14-1.62	0.0007
Adult LVH	1.52	1.18-1.94	0.001	1.59	1.27-1.99	<0.001

NIH/NHLBI, National Institutes of Health's National Heart, Lung, and Blood Institute.

All analyses were adjusted for race, sex, age, childhood body mass index, and length of follow-up.

Table 3.

Classification matrix based on the 2004 or 2017 pediatric blood pressure (BP) classification

2004 NIH/NHLBI guidelines	2017 American Academy of Pediatrics guidelines			
Classification	**Normal BP**	**Elevated BP**	**Stage 1 hypertension**	**Stage 2 hypertension**
Normal BP	2812	108	1	0
Prehypertension	12	550	188	4
Stage 1 hypertension	0	26	192	28
Stage 2 hypertension	0	0	0	19

The values are numbers of individual participants in the Bogalusa Heart Study.

NIH/NHLBI, National Institutes of Health's National Heart, Lung, and Blood Institute.

Table 4

Characteristics of the 329 children reclassified upward under the 2017 pediatric guidelines vs propensity score -matched normotensive children

Variable	Normotensive children (n=329)	Children reclassified upward (n=329)	P
Male (%)	63	62	0.64
Whites (%)	67	64	0.17
Baseline childhood characteristics			
Age (years)	9±3	9±3	0.22
Height percentile	52±28	53±27	0.37
BMI (kg/m^2)	17±3	18±4	0.028
SBP (mmHg)	98±9	107±10	<0.001
DBP (mmHg)	51±9	54±10	<0.001
TC (mg/dl)	162±28	168±30	0.03
Ln TG (mg/dl)	4.1±0.5	4.2±0.4	0.81
LDL-C (mg/dl)	90±25	92±27	0.22
HDL-C (mg/dl)	64±22	66±21	0.14
FPG (mmol/l)	4.6±0.5	4.6±0.5	0.11
2004 SBP percentile	39±21	66±23	<0.001
2004 DBP percentile	27±20	37±25	<0.001
2017 DBP percentile	26±21	37±26	<0.001
2017 SBP percentile	43±23	71±23	<0.001
Obesity (%)	3	10	0.0001
TC Borderline high/High (%)	35	43	0.03
TG Borderline high/High (%)	18	21	0.22
LDL Borderline high/High (%)	19	18	0.51
HDL Borderline low/Low (%)	15	14	0.72
Follow-up adult characteristics			
Age (years)	35±12	35±12	0.77
BMI (kg/m^2)	28±7	29±7	0.33
WC (cm)	91±18	93±18	0.20
SBP (mmHg)	117±12	123±15	<0.001
DBP (mmHg)	72±11	74±13	0.02
TC (mg/dl)	182±37	186±39	0.2
Ln TG (mg/dl)	4.7±0.6	4.7±0.6	0.90
LDL-C (mg/dl)	113±33	115±34	0.58
HDL-C (mg/dl)	50±17	47±14	0.02
FPG (mmol/l)	5.2±1.9	5.2±1.7	0.76
LVMI (g/m $^{2.7}$)	38±10	44±21	0.006
Hypertension (%)	23	41	<0.001
MetS (%)	22	30	0.03
LVH (%)	16	29	0.01

Values are mean±SDs or percentages.

BMI, Body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglycerides; LDL-C, low density lipoprotein cholesterol; HDL-C high density lipoprotein cholesterol; FPG, fasting plasma glucose, WC, waist circumference; LVMI, left ventricular mass index; MetS, metabolic syndrome; LVH, left ventricular hypertrophy

Table 5.

Odds ratios and 95% confidence intervals for adult hypertension, metabolic syndrome (MetS), and left ventricular hypertrophy (LVH) among the 329 individuals who were reclassified upward under the 2017 pediatric guidelines compared to the propensity score-matched normotensive children

Health Outcome		Odds ratio	95% confidence interval
Adult hypertension	Model 1	2.37	1.67-3.35
	Model 2	2.20	1.54-3.13
	Model 3	2.12	1.48-3.04
Adult MetS	Model 1	1.50	1.07-2.31
	Model 2	1.49	1.01-2.22
	Model 3	1.43	1.01-2.19
Adult LVH	Model 1	2.18	1.23-3.88
	Model 2	2.06	1.14-3.72
	Model 3	2.05	1.12-3.75

Model 1 was unadjusted.

Model 2 was adjusted for childhood body mass index.

Model 3 was adjusted for childhood body mass index and total cholesterol.