Prehypertension and Hypertension in Community-Based Pediatric Practice

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KEY WORDS
hypertension, prehypertension, pediatrics, blood pressure, databases, health information technology, electronic health records

ABBREVIATIONS
BP—blood pressure
HPMG—HealthPartners Medical Group
KPNC—Kaiser Permanente Northern California
KPCO—Kaiser Permanente Colorado

Dr Lo supervised the team, conceptualized and designed the study, contributed substantively to the analysis and interpretation of data, drafted the initial manuscript, and approved the final manuscript as submitted; Dr Sinaiko provided substantive contribution to the conception and design of the study and analysis and interpretation of data, drafted portions of the manuscript, revised the manuscript for important intellectual content, and approved the final manuscript as submitted; Ms Chandra provided substantive contribution to the design of the study, collected the data, conducted all data analyses, revised the manuscript for important intellectual content, and approved the final manuscript as submitted; Drs Daley, Greenspan, Kharbanda, Margolis, Adams, and Prineas provided substantive contribution to the analysis and interpretation of data, revised the manuscript for important intellectual content, and approved the final manuscript as submitted; Dr Parker led the statistical analyses, contributed to the interpretation of data, revised the manuscript for important intellectual content, and approved the final manuscript as submitted; Dr Magid supervised the team and provided substantive contribution to the design of the study, analysis and interpretation of data, revision of the manuscript for important intellectual content, and approved the final manuscript as submitted; and Dr. O'Connor obtained funding, supervised the team, provided substantive contribution to the conception and design of the study and analysis and interpretation of data, drafted portions of the manuscript, revised the manuscript for important intellectual content, and approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Prevalence of hypertension in children increased significantly over the past few decades, tracks into adulthood, and is a major risk factor for cardiovascular disease. However, current prevalence estimates in children have largely been based on studies conducted in school environments.

WHAT THIS STUDY ADDS: The current study reports the prevalence of childhood hypertension in community pediatric practice, which provides a typical pediatric examination environment, unlike blood pressure measured in school. The results show a significantly lower prevalence than what has previously been reported.

abstract

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OBJECTIVE: To examine the prevalence of prehypertension and hypertension among children receiving well-child care in community-based practices.

METHODS: Children aged 3 to 17 years with measurements of height, weight, and blood pressure (BP) obtained at an initial (index) well-child visit between July 2007 and December 2009 were included in this retrospective cohort study across 3 large, integrated health care delivery systems. Index BP classification was based on the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents: normal BP, <90th percentile; prehypertension, 90th to 94th percentile; hypertension, 3 BP measurements ≥95th percentile (index and 2 subsequent consecutive visits).

RESULTS: The cohort included 199 513 children (24.3% aged 3–5 years, 34.5% aged 6–11 years, and 41.2% aged 12–17 years) with substantial racial/ethnic diversity (35.9% white, 7.8% black, 17.6% Hispanic, 11.7% Asian/Pacific Islander, and 27.0% other/unknown race). At the index visit, 81.9% of participants were normotensive, 12.7% had prehypertension, and 5.4% had a BP in the hypertension range (≥95th percentile). Of the 10 848 children with an index hypertensive BP level, 3.8% of those with a follow-up BP measurement had confirmed hypertension (estimated 0.3% prevalence). Increasing age and BMI were significantly associated with prehypertension and confirmed hypertension ($P < .001$ for trend). Among racial/ethnic groups, blacks and Asians had the highest prevalence of hypertension.

CONCLUSIONS: The prevalence of hypertension in this community-based study is lower than previously reported from school-based studies. With the size and diversity of this cohort, these results suggest the prevalence of hypertension in children may actually be lower than previously reported. *Pediatrics* 2013;131:e415–e424

In the past 2 decades there has been increased recognition of the importance of blood pressure (BP) measurement in the pediatric population,[1,2] particularly in relation to the rising prevalence of childhood obesity.[3] However, the importance of BP goes beyond its relation to obesity, because longitudinal studies reveal a relation between childhood BP and future cardiovascular risk factors in young adults, independent of BMI.[4] Data from pediatric BP screening programs and the NHANES support early detection and management of hypertension in pediatric practice, particularly given its association with excess weight and other cardiovascular risk factors[1,5–9] and the increasing awareness of childhood origins of adult disease.[10]

Epidemiologic BP screening studies conducted in large school systems with the use of carefully controlled measurement protocols show that many children with an initially elevated BP have normal BP on repeated measurements over relatively short periods of time.[5,7,11,12] This significant reduction in hypertension prevalence after repeated measurement emphasizes that a single elevated BP is insufficient for clinical diagnosis in children.[12]

The recent availability of automated electronic medical records in large health plans has enabled the examination of BP in pediatric populations across community-based clinical settings[13] and presents a unique opportunity to compare these data with published epidemiologic studies of pediatric hypertension. In the current study, data were obtained from automated clinic records in a multiethnic population of children receiving care within 3 large, community-based US health plans. The results present a contemporary assessment of what pediatricians in similar general practices can expect in terms of BP measurement when seeing a child for the first time and provide useful estimates of the prevalence of hypertension across age, gender, and racial/ethnic subgroups among children receiving pediatric well-child care.

METHODS

Kaiser Permanente Northern California (KPNC), Kaiser Permanente Colorado (KPCO), and HealthPartners Medical Group (HPMG) are integrated health care delivery systems providing care to >4 million members living primarily in urban and suburban communities in Northern California, Colorado, and Minnesota. Their memberships are racially and ethnically diverse, and children younger than age 18 years constitute 20% to 25% of the total membership. All 3 health systems have used similar integrated electronic medical records: KPCO and HPMG for >6 years and KPNC for up to 4 years (in the 3 subregions used for this study). The current study includes all children aged 3 to 17 years with an initial (index) measurement of BP, height, and weight obtained at a well-child visit between July 1, 2007 to December 31, 2009. Follow-up BP measurements from outpatient non–urgent care visit settings were used for hypertension classification through December 31, 2010, with a total observation/follow-up period of 3.5 years. Membership in the health plan for 6 months before the index visit and pharmacy benefits were required to ascertain treatment with BP-lowering medication before the index visit.

At each site, weight was measured on a calibrated scale and height by stadiometer. The specific methods for BP assessment varied by health plan. At KPNC, BP was measured by trained medical assistants with the use of oscillometric devices that were calibrated periodically. At KPCO and HPMG, BP was measured by trained staff predominantly by using aneroid sphygmomanometers recalibrated as needed by bioengineering services. All measurements were conducted with children in the seated position with selection of cuff size appropriate to arm size. BP standards from the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents were used to classify BP according to gender, age, and height.[10] Children with systolic and diastolic BP <90th percentile for height at the index visit were classified as having normal BP. Children with systolic or diastolic BP between the 90th and 95th percentile (or ≥120/80 mm Hg for adolescents) were classified as prehypertensive. Hypertension was defined by BP ≥95th percentile at the index visit and at 2 subsequent consecutive visits within ≤3.5 years of follow-up. For subsequent pediatric BP without height measurement, the closest height within 6 months was used to calculate the BP percentile; for subsequent BP obtained at age ≥18 years (0.3% of children), a criterion of SBP ≥140 and/or DBP ≥90 mmHg was used.

Information pertaining to age, gender, race/ethnicity, height, weight, and systolic and diastolic BP measurements were obtained from the electronic medical record for the index and subsequent outpatient visits. BMI percentiles representing conventional pediatric categories (<85th percentile = normal, 85th–94th percentile = overweight, ≥95th percentile = obese, and ≥99th percentile = severely obese)[14,15] were based on the 2000 Centers for Disease Control and Prevention growth charts.[16] Treatment with antihypertensive medications was assessed by using pharmacy dispensing records, and individuals receiving an antihypertensive medication prescription in the 6 months before the index visit were excluded from the cohort (n = 785). The majority of these excluded children

(63.2%) received guanfacine and clonidine, drugs typically used for developmental and behavioral indications and rarely used to treat hypertension in the pediatric population. Of the remaining 289 children, 183 did not have hypertension diagnoses. Only 106 had diagnoses of hypertension (n = 55) or elevated BP (n = 4) or had received hypertension screening (n = 47). Because it was not possible to confirm the hypertension diagnosis and because the purpose of this study was to assess prevalence on the basis of an index BP measurement, these children were excluded.

The Institutional Review Board at HealthPartners Institute for Education and Research approved the study, with ceding of oversight authority by the KPNC and KPCO Institutional Review Boards. A waiver of informed consent was obtained due to the nature of the study.

Differences across subgroups were compared by using the χ^2 test. The Cochrane-Armitage test was used to examine trends across age and BMI percentile strata. Point estimates and 95% confidence intervals were calculated for the prevalence of elevated BP. All analyses were conducted with the use of SAS, version 9.1 (SAS Institute, Cary, NC). A 2-tailed α of $<$0.05 was chosen as the criterion for significance.

RESULTS

The initial source population included 342 323 children and adolescents aged 3 to 17 years with ≥1 outpatient visits between July 1, 2007, and December 31, 2009. After excluding children without a well-child visit with measurements of height, weight, and systolic and diastolic BP and those not meeting membership criteria, the final cohort consisted of 199 513 children and adolescents, half of whom were female (Table 1). Of these, 24.3% were aged 3 to 5 years, 34.5% aged 6 to 11 years, 21.8% aged 12 to 14 years, and 19.4% aged 15 to 17 years. The cohort was racially and ethnically diverse: 35.9% were non-Hispanic white, 7.8% were non-Hispanic black, 17.6% were Hispanic, 11.7% were Asian/Pacific Islander (PI), and 27.0% were of other or unknown race. A total of 14.3% were obese, defined by a BMI ≥95th percentile according to age and gender. Compared with children in the source population, those in the study cohort were more likely to be younger (80.6% vs 70.2% younger than age 15 years) and slightly more likely to be white (35.9% vs 32.4%), with no difference in gender.

Mean BP, height, and weight across gender, age, race/ethnicity, and BMI subgroups are shown in Table 1. As expected, systolic and diastolic BP increased by age group and BMI percentile, and anthropometric measures (height and weight) increased by age and varied by gender and race/ethnicity. The mean values at each age are provided in Appendixes 1 and 2.

At the index visit, 163 295 (81.9%) of the cohort were normotensive, 25 370 (12.7%) had BP in the prehypertension range (90th–94th percentile), and 10 848 (5.4%) had BP ≥95th percentile (Table 2). Among the 10 848 with an elevated index BP ≥95th percentile, 6739 (62.1%) had 1 to 2 more subsequent ambulatory visits allowing final BP assignment, including 6482 with a second or third consecutive BP $<$95th percentile. Only 257 had 2 subsequent consecutive BP measurements that met the Task Force Report criteria for hypertension,[10] representing 3.8% of those with a BP ≥95th percentile and subsequent BP measurement. However, an additional 29 children began taking antihypertensive medication before the second or third measurement. The inclusion of these 29 children with the 257 children translates to an overall prevalence of hypertension of 0.14% (95% confidence interval: 0.12%, 0.16%). The prevalence of hypertension was low at each of the 3 sites, ranging from 0.04% to 0.17%. Among the 4109 children with an index BP ≥95th percentile who did not have a second (n = 3571) or third (n = 538) BP percentile available during the longitudinal follow-up period, 65% were younger than age 12 years. Compared with the children with follow-up measurements, a slightly greater proportion of those without follow-up BP were overweight or obese (52.3% vs 48.5%, $P < .01$) and of nonwhite or unknown race (77.4% vs 68.8%, $P < .01$), but did not differ by gender. If the assumption is made that a similar percentage (eg, 3.8%) of the 4109 children without follow-up would have met criteria for hypertension had they been seen for repeated BP measurements,[5] the estimated number of hypertensive children would increase from 257 to 413 or 0.2% of the overall cohort. If these analyses were restricted to the 85 780 children with an index visit and 2 subsequent visits with BP measurements, the prevalence of normotensive BP would be 83.4%, prehypertension would be 12.0%, and confirmed hypertension would increase to 0.3%.

Table 2 shows BP classification by age group, gender, race/ethnicity, and BMI. The percentage of boys with normal BP was significantly lower and there was a greater percentage with prehypertension, but the percentage with hypertension was similar between genders. Older age was associated with a lower percentage with normal BP and a higher percentage with prehypertension (both $P < .0001$ for trend). The youngest age group (3–5 years) had the highest percentage with an index BP in the hypertensive range (≥95th percentile), but in those with 3 consecutive BP measurements, hypertension was directly related to older

TABLE 1 BP, Height, Weight, and BMI by Age, Gender, Race/Ethnicity, and BMI Category in Children and Adolescents Aged 3–17 Years Old

	Boys (N = 100 806)						Girls (N = 98 707)					
	n (%)	SBP	DBP	Height	Weight	BMI	n (%)	SBP	DBP	Height	Weight	BMI
Age group												
3–5 y	24 779 (24.6)	94.6 ± 9.3 mm Hg	56.2 ± 8.1 mm Hg	105.8 ± 6.3 cm	18.2 ± 17.7 kg	16.2 ± 1.8	23 690 (24.0)	94.0 ± 9.3 mm Hg	56.6 ± 8.2 mm Hg	105.0 ± 6.3 cm	17.7 ± 3.2 kg	15.9 ± 1.8
6–11 y	35 274 (35.0)	101.5 ± 10.2 mm Hg	60.3 ± 8.2 mm Hg	134.4 ± 11.9 cm	34.2 ± 11.6 kg	18.5 ± 3.9	33 643 (34.1)	100.9 ± 10.3 mm Hg	60.3 ± 8.2 mm Hg	134.7 ± 12.8 cm	34.1 ± 12.1 kg	18.3 ± 3.9
12–14 y	21 645 (21.5)	110.6 ± 11.3 mm Hg	63.8 ± 8.3 mm Hg	162.0 ± 9.9 cm	57.6 ± 16.2 kg	21.7 ± 4.9	21 833 (22.1)	107.6 ± 10.7 mm Hg	63.7 ± 8.2 mm Hg	158.3 ± 7.2 cm	55.5 ± 14.1 kg	22.0 ± 4.9
15–17 y	19 108 (19.0)	116.0 ± 11.4 mm Hg	66.2 ± 8.5 mm Hg	173.9 ± 7.6 cm	72.2 ± 17.8 kg	23.8 ± 5.3	19 541 (19.8)	109.7 ± 10.7 mm Hg	65.4 ± 8.2 mm Hg	162.0 ± 6.8 cm	62.3 ± 15.0 kg	23.7 ± 5.2
Race/ethnicity, percentile												
White	36 490 (36.2)	44 (22–68)	52 (34–70)	59 (34–80)	64 (38–85)	62 (35–86)	35 074 (35.5)	44 (22–70)	49 (31-68)	58 (33–80)	63 (38–83)	63 (37–84)
Black	7892 (7.8)	53 (29–76)	54 (36–73)	63 (38–83)	75 (50–91)	74 (48–92)	7693 (7.8)	54 (29–77)	54 (34-73)	65 (38–84)	76 (51–92)	77 (50–92)
Hispanic	18 015 (17.9)	53 (30–76)	57 (38–74)	51 (28–75)	72 (44–92)	78 (50–95)	17 168 (17.4)	52 (28–76)	54 (35-73)	47 (23–72)	68 (41–89)	76 (50–92)
Asian/PI	12 214 (12.1)	57 (34–79)	60 (40–77)	43 (20–68)	58 (29–84)	66 (36–89)	11 021 (11.2)	54 (31–76)	57 (36-75)	39 (18–65)	50 (25–75)	59 (33–82)
Other/unknown	26 195 (26.0)	50 (26–75)	53 (35–71)	53 (29–76)	66 (38–88)	68 (39–90)	27 751 (28.1)	51 (26–75)	52 (33-71)	50 (25–74)	62 (35–84)	67 (39–87)
BMI percentile												
<85th	69 045 (68.5)	44 (23–68)	52 (34–71)	50 (26–74)	50 (28–69)	51 (28–70)	70 682 (71.6)	44 (22–69)	50 (32-69)	49 (25-73)	49 (27–68)	53 (30–71)
85th–94th	15 413 (15.3)	55 (31–77)	55 (37–73)	60 (36–81)	88 (80–93)	91 (88–93)	15 928 (16.1)	56 (33–79)	54 (35-72)	58 (32-79)	87 (80–92)	90 (88–93)
95th–98th	12 113 (12.0)	66 (41–85)	59 (40–76)	67 (42–85)	97 (94–98)	97 (96–98)	9835 (10.0)	67 (42–86)	60 (39-77)	66 (40-85)	97 (94–98)	97 (96–98)
≥99th	4235 (4.2)	74 (51–90)	67 (47–82)	74 (49–88)	100 (99–100)	99 (99–100)	2262 (2.3)	78 (55–92)	68 (47-84)	76 (53-90)	100 (99–100)	99 (99–100)

Data by age group are presented as means ± SD unless otherwise indicated. Data for race/ethnicity and BMI classification are presented as age-adjusted percentiles (median and interquartile range). BMI percentiles were based on the 2000 Centers for Disease Control and Prevention growth charts[16] are classified as follows: 85th–94th percentile = overweight, 95th–98th percentile = obese, ≥99th percentile = severely obese (as discussed in Methods). DBP, diastolic blood pressure; SBP, systolic blood pressure.

age (P for trend $<$ .0001). Index BP classification by each age and gender is provided in Appendixes 3 and 4.

As BMI percentile increases from normal to obese, the likelihood of a normal index BP decreased whereas the likelihood of an index BP in the prehypertensive and hypertensive range increased (all $P < .0001$ for trend, Table 2). The highest proportion with confirmed hypertension was seen in children with a BMI ≥99th percentile (1.0% overall and 2.6% among those with 3 consecutive visits). Similarly, as BP percentile increased, the proportion in the normal BMI percentile decreased and the likelihood of overweight and obesity increased (Fig 1). However, nearly half of those classified as having hypertension had BMIs in the non-obese range.

There were significant differences in BP by race/ethnicity (Table 2). In particular, a greater percentage of nonwhites had prehypertension than did whites (all $P < .01$), with blacks having the lowest percentage with normal BP and the greatest percentage with prehypertension compared with Asians and Hispanics. Blacks and Asians had the highest percentage with hypertension, which was significantly greater than that for whites (both $P \leq .01$). Asian/PI ($P < .01$) but not blacks ($P = .15$) also had a greater percentage of children with hypertension than did Hispanics. Whites and Hispanics did not differ with respect to prevalence of hypertension ($P = .25$).

DISCUSSION

This collaborative report is one of the first from major community-based pediatric practices that describes the prevalence of hypertension using the criteria published in the Fourth Task Force report.[10] Because of the large cohort size of nearly 200 000, it was also possible to make comparisons among children across the entire

TABLE 2 BP Classification of 199 513 Children and Adolescents Aged 3–17 Years by Age, Gender, Race/Ethnicity, and BMI

	n	Normal BP at Index Visit (*n* = 163 295)	Prehypertension at Index Visit (*n* = 25 370)	BP ≥95th Percentile at Index Visit (*n* = 10 848)	Assessment of BP in Children with Index BP ≥95th Percentile (*n* = 10 848)		
					Repeat BP <95th Percentile (*n* = 6482)	No Repeat BP (*n* = 4109)	Hypertension (3 BP Measurements ≥95th Percentile) (*n* = 257)
Age group, *n* (%)		[a]	[a]	[a]			[a]
3–5 y	48 469	41 355 (85.3)	4017 (8.3)	3097 (6.4)	1967 (4.1)	1083 (2.2)	47 (0.10)
6–11 y	68 917	60 921 (88.4)	4505 (6.5)	3491 (5.1)	1850 (2.7)	1585 (2.3)	56 (0.08)
12–14 y	43 478	34 460 (79.3)	6668 (15.3)	2350 (5.4)	1415 (3.3)	858 (2.0)	77 (0.18)
15–17 y	38 649	26 559 (68.7)	10 180 (26.3)	1910 (4.9)	1250 (3.2)	583 (1.5)	77 (0.20)
Gender, *n* (%)		[b]	[b]	[c]			
Female	98 707	83 316 (84.4)	9907 (10.0)	5484 (5.6)	3271 (3.3)	2084 (2.1)	129 (0.13)
Male	100 806	79 979 (79.3)	15 463 (15.3)	5364 (5.3)	3211 (3.2)	2025 (2.0)	128 (0.13)
Race/ethnicity, *n* (%)							
Non-Hispanic white	71 564	60 092 (84.0)[d]	8438 (11.8)[d]	3034 (4.2)[d]	2035 (2.8)	929 (1.3)	70 (0.10)[e]
Non-Hispanic black	15 585	12 226 (78.5)[d]	2413 (15.5)[d]	946 (6.1)[f]	590 (3.8)	329 (2.1)	27 (0.17)[g]
Hispanic	35 183	28 686 (81.5)[d]	4372 (12.4)[h]	2125 (6.0)[f]	1326 (3.8)	756 (2.2)	43 (0.12)[i]
Asian/PI	23 235	18 611 (80.1)[d]	2952 (12.7)[h]	1672 (7.2)[d]	955 (4.1)	664 (2.9)	53 (0.23)[j]
Other/unknown	53 946	43 680 (81.0)	7195 (13.3)	3071 (5.7%)	1576 (2.9)	1431 (2.7)	64 (0.12)
BMI percentile, *n* (%)		[a]	[a]	[a]			[a]
<85th	139 727	120 097 (86.0)	14 199 (10.2)	5431 (3.9)	3390 (2.4)	1960 (1.4)	81 (0.06)
85th–94th	31 341	24 467 (78.1)	4919 (15.7)	1955 (6.2)	1156 (3.7)	753 (2.4)	46 (0.15)
95th–98th	21 948	15 119 (68.9)	4556 (20.8)	2273 (10.4)	1309 (6.0)	901 (4.1)	63 (0.29)
≥99th	6497	3612 (55.6)	1696 (26.1)	1189 (18.3)	627 (9.7)	495 (7.6)	67 (1.03)

Classification of hypertension based on the Fourth Task Force report[10] required 3 consecutive BP measurements ≥95th percentile. A subset of children had an elevated index BP without repeat measurement. BMI percentiles were based on the 2000 Centers for Disease Control and Prevention growth charts[16] and are classified as follows: 85th–94th percentile = overweight, 95th–98th percentile = obese, ≥99th percentile = severely obese (as discussed in Methods).

[a] $P < .0001$ for trend across increasing age group and BMI percentile.
[b] $P < .001$ for male versus female.
[c] $P < .05$ for male versus female.
[d] $P < .01$ compared with all other race/ethnic groups (white, black, Hispanic, or Asian/PI).
[e] $P < .05$ compared with black and Asian race.
[f] $P < .001$ compared with white or Asian race.
[g] $P = .01$ compared with white race.
[h] $P < .01$ compared with white or black race.
[i] $P < .01$ compared with Asian race.
[j] $P < .01$ compared with white or Hispanic race/ethnicity.

pediatric age range (3–17 years), BMI category (normal to obese), gender, and race/ethnicity. The results reveal that the great majority of children seen in routine well-child care in pediatric practices have normal BP, 12.7% have BP in the prehypertension range, 5.4% have an initial systolic or diastolic BP ≥95th percentile for gender, age, and height, but the prevalence of hypertension, as defined by 3 consecutive hypertensive BP ≥95th percentile, was <1% overall and within each health plan.

The percentage of children in this study with an initially hypertensive BP is slightly lower compared with the only other previous report (7.2%) from a community-based health plan that included data on initial BP measurements.[13] However, it is within the range reported from previous prevalence studies conducted primarily in junior high– or high school–aged children, ranging from 2.7% in Minnesota to 19.4% in Texas,[7,11,17,18] and from estimates using NHANES data from 2003 to 2006 in which the prevalence of an initial hypertensive BP range was 2.6% among 13- to 17-year-olds.[19] The prevalence of prehypertension was similarly related to both age and BMI. Although the significant reduction in prevalence of confirmed hypertension from the initial (index) measurement to the third consecutive measurement was expected and followed previously described patterns, the rather low estimated prevalence of confirmed hypertension (0.3% overall) in this study was surprising and substantially lower than the prevalence of 0.8% to 4.5% reported in previous studies.[7,11,17,18,20] Although 38% of children with an initially hypertensive BP did not return for additional BP measurements, it seems unlikely that this had a major effect on prevalence, because they were not substantially different from those children who returned. The frequency of 3 consecutive elevated BPs would have to be >10 times higher in those without follow-up for an overall prevalence of 1%. This is not likely given that the majority were younger than age 12 years, an age group in which the prevalence of confirmed hypertension is low.

Several factors may explain the lower prevalence of hypertension in this cohort compared with findings from other studies. Previous studies may have less diverse patient populations and be less generalizable than the current study, which did not focus on a single geographic region. The lower prevalence in this study may reflect the inclusion of preschool and grade school children, as opposed to studying only junior high– and high school–aged children,[7,11,17,18] the lower number of non-Hispanic blacks, or the lower number of overweight/ obese children. However, even in the oldest age group (15–17 years), and among black and obese children, the prevalence of hypertension, although higher than in the other groups, remained low. Even if we had included the 106 children receiving previous antihypertensive medication, the prevalence would have increased only by 0.05%. A previous report from another cohort with a similar age distribution (3–18 years) reported a hypertension prevalence of 3.6%.[20] That study was conducted over 7 years and appears

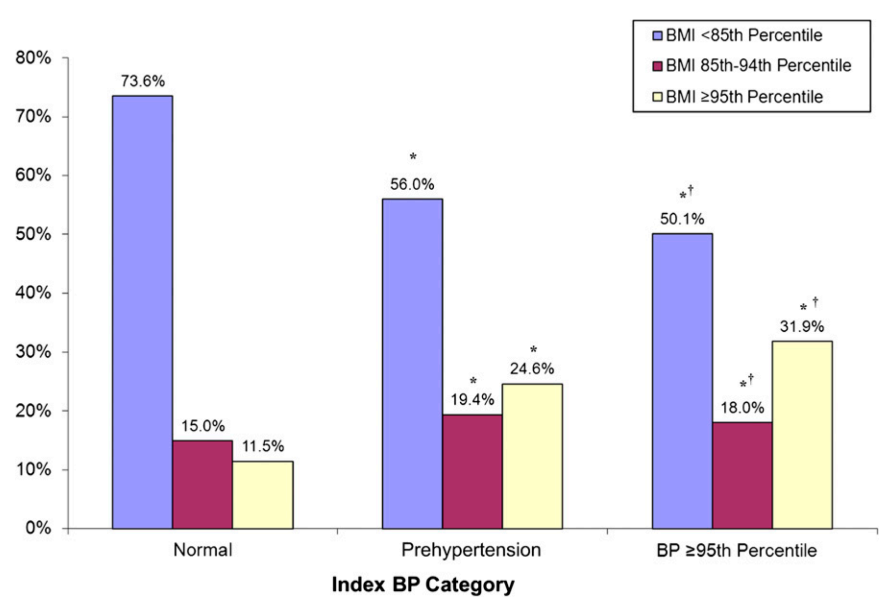

FIGURE 1
BP status by proportion of children with BMI classified as normal (BMI <85th percentile), overweight (BMI 85th–94th percentile), or obese (BMI ≥95th percentile). *$P < .01$ compared with corresponding BMI category for normal BP. †$P < .01$ compared with corresponding BMI category for prehypertension status.

to have used 3 nonconsecutive hypertensive BP levels, rather than 3 consecutive hypertensive levels.[20] Those results and others suggest that protocols using longer periods of observation, >3 measurements, nonconsecutive hypertensive levels, or the average of many measurements rather than only the hypertensive levels should be compared with the currently recommended approach of using 3 consecutive hypertensive levels to diagnose hypertension in children. It is also possible that, despite the large size of this cohort, it was not truly representative of a natural distribution of children; the children were largely from families with health insurance and may have had higher socioeconomic status or healthier family lifestyles. The prevalence of obesity in our cohort was 14.3%, which is somewhat lower than the national estimate of 16.9% reported from the NHANES conducted in 2009–2010.[21] We also focused our study on children receiving well-child care, which may preferentially reflect a healthier population of children and families accessing preventive care services who perhaps are less likely to have hypertension. Finally, because BP was measured in clinic settings that were familiar to the children, as opposed to the specific atypical activity of having BP measured in school, the accommodation effect of repeated BP assessment might have been enhanced.

BP is known to be directly related to BMI across all age groups,[10,13,19] as is evident in this study in which both prehypertension and index hypertensive measurements directly and strongly related to higher BMI percentile. The prevalence of confirmed hypertension also increased substantially with increasing BMI, although it remained relatively low even among obese children. It is known that levels of other cardiovascular risk factors are often higher in overweight and obese children.[22,23] Whereas assessment of BP is important to childhood and adolescent care, these data suggest that even in overweight and obese children, a single elevated BP measure requires careful confirmation before diagnosing hypertension.

Compared with other race/ethnic subgroups, there was a lower percentage of black children with normal BP and a higher percentage with prehypertension and hypertension. Children of Asian/PI heritage also showed a higher prevalence of hypertension, but there were no significant differences in the proportion with hypertension between the other ethnic groups.

There were some limitations associated with this study. First, this study examined BP measurements obtained at preventive care visits with predominantly aneroid manometers at KPCO and HPMG and with oscillometric devices at KPNC. Oscillometric systolic BP readings are known to be slightly higher than those obtained by auscultatory measurement.[10] However, these methodologic differences likely had little substantial effect on the results, given the low prevalence of hypertension overall. Also, because this was a retrospective study with clinical data collected from a large number of clinics, technique could not be monitored at each site; although each clinic measured BP in the seated position with appropriate cuff size, there was no standardized training for measuring height, weight, or BP and no standardized time interval for a return to clinic after an elevated BP. Second, most subjects were insured, and the low rates of observed hypertension prevalence could be related to underrepresentation of socially disadvantaged youth in this cohort. Third, a number of subjects with index hypertensive BP were missing a second or third BP measurement required for the diagnosis of hypertension (38%); however, assuming the percentage with hypertension in this group was similar to the group who returned for repeat measurements (ie, 3.8%), the prevalence of hypertension would increase only from 0.13% to 0.2%. It is unlikely, based on observed patterns of BP at the index and follow-up visits, that the study conclusions would have been significantly altered had the missing BPs been obtained. Finally, although this study used consecutive BP measurements ≥95th percentile to diagnose hypertension, as recommended by the Task Force report, the period of observation was over 3.5 years. Repeating the measurements over a shorter period of time, similar to previous epidemiologic BP studies in children, may lead to an increased prevalence of hypertension. Nonetheless, it seems reasonable to suggest that a true diagnosis of hypertension should be sustainable over longer periods of observation.

In summary, this study describes the prevalence of hypertension in 3 large community-based, geographically diverse pediatric practices from predominantly urban or suburban communities. The results from data in nearly 200 000 children suggest that in community-based practices in settings similar to those in this study, the prevalence of pediatric hypertension and prehypertension may be substantially lower across a wide range of age, race/ethnicity, and adiposity status than suggested in previous studies.

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APPENDIX 1 BP, Height, Weight, and BMI by Age in 100 806 Boys Aged 3–17 Years

Age, y	*n* (%)	SBP, mm Hg	DBP, mm Hg	Height, cm	Weight, kg	BMI
3	4664 (4.6)	93.2 ± 9.2	55.1 ± 8.1	99.4 ± 4.5	16.2 ± 2.4	16.3 ± 1.5
4	12 354 (12.3)	94.5 ± 9.2	56.3 ± 8.0	104.8 ± 4.5	17.7 ± 2.6	16.1 ± 1.7
5	7761 (7.7)	95.6 ± 9.4	56.7 ± 8.1	111.4 ± 4.8	20.1 ± 3.4	16.2 ± 2.1
6	5321 (5.3)	97.6 ± 9.4	57.8 ± 8.1	118.2 ± 5.1	23.2 ± 4.5	16.5 ± 2.4
7	5082 (5.0)	98.8 ± 9.5	58.7 ± 7.8	124.9 ± 5.5	26.8 ± 6.0	17.1 ± 3.0
8	5818 (5.8)	100.7 ± 9.7	59.8 ± 8.1	130.9 ± 5.9	31.1 ± 7.5	18.0 ± 3.4
9	5583 (5.5)	101.9 ± 9.8	60.8 ± 7.9	136.4 ± 6.1	35.2 ± 8.7	18.8 ± 3.8
10	5951 (5.9)	103.3 ± 10.0	61.4 ± 8.1	142.0 ± 6.7	39.8 ± 10.6	19.6 ± 4.1
11	7519 (7.5)	104.9 ± 10.4	62.3 ± 8.1	147.7 ± 7.2	44.4 ± 12.0	20.2 ± 4.4
12	6942 (6.9)	107.4 ± 10.9	62.9 ± 8.2	154.4 ± 7.9	50.5 ± 13.9	21.0 ± 4.7
13	6467 (6.4)	110.8 ± 11.0	63.8 ± 8.3	162.1 ± 8.3	57.4 ± 15.2	21.7 ± 4.8
14	8236 (8.2)	113.1 ± 11.2	64.7 ± 8.4	168.3 ± 7.8	63.9 ± 16.2	22.4 ± 5.0
15	7281 (7.2)	114.8 ± 11.3	65.5 ± 8.3	172.3 ± 7.6	69.2 ± 17.4	23.2 ± 5.2
16	6191 (6.1)	116.4 ± 11.3	66.2 ± 8.6	174.4 ± 7.4	72.9 ± 17.6	23.9 ± 5.3
17	5636 (5.6)	117.2 ± 11.5	67.0 ± 8.6	175.4 ± 7.5	75.2 ± 17.9	24.4 ± 5.4

Data are presented as means ± SD unless otherwise indicated. DBP, diastolic blood pressure; SBP, systolic blood pressure.

APPENDIX 2 BP, Height, Weight, and BMI by Age in 98 707 Girls Aged 3–17 Years

Age, y	*n* (%)	SBP, mm Hg	DBP, mm Hg	Height, cm	Weight, kg	BMI
3	4382 (4.4)	92.7 ± 9.4	55.5 ± 8.5	98.5 ± 4.3	15.6 ± 2.3	16.1 ± 1.7
4	11 814 (12.0)	93.9 ± 9.2	56.7 ± 8.0	103.8 ± 4.5	17.1 ± 2.6	15.9 ± 1.7
5	7494 (7.6)	94.9 ± 9.4	57.0 ± 8.2	110.6 ± 4.8	19.7 ± 3.4	16.0 ± 2.0
6	5115 (5.2)	96.9 ± 9.5	57.7 ± 8.0	117.6 ± 5.2	22.8 ± 4.5	16.4 ± 2.4
7	4844 (4.9)	97.9 ± 9.6	58.9 ± 7.9	123.9 ± 5.5	26.1 ± 5.7	16.9 ± 2.8
8	5138 (5.2)	99.9 ± 9.7	59.7 ± 8.1	130.0 ± 5.9	30.2 ± 7.4	17.7 ± 3.4
9	5339 (5.4)	101.2 ± 10.0	60.4 ± 8.1	136.1 ± 6.5	34.7 ± 9.0	18.6 ± 3.8
10	5537 (5.6)	103.2 ± 10.2	61.5 ± 8.0	142.7 ± 7.1	39.7 ± 10.8	19.3 ± 4.1
11	7670 (7.8)	104.3 ± 10.3	62.2 ± 8.0	149.2 ± 7.3	45.0 ± 12.3	20.0 ± 4.4
12	7116 (7.2)	106.5 ± 10.5	63.0 ± 8.2	155.0 ± 7.0	51.4 ± 13.5	21.2 ± 4.8
13	6477 (6.6)	107.7 ± 10.8	63.7 ± 8.2	158.8 ± 6.8	55.9 ± 13.8	22.1 ± 4.8
14	8240 (8.4)	108.5 ± 10.7	64.2 ± 8.1	160.8 ± 6.7	58.8 ± 14.0	22.7 ± 4.9
15	7325 (7.4)	108.9 ± 10.6	64.9 ± 8.2	161.7 ± 6.8	61.2 ± 14.3	23.4 ± 5.0
16	6244 (6.3)	110.0 ± 10.7	65.4 ± 8.1	162.0 ± 6.8	62.3 ± 15.1	23.7 ± 5.3
17	5972 (6.1)	110.3 ± 10.9	66.0 ± 8.4	162.4 ± 6.8	63.6 ± 15.6	24.1 ± 5.4

Data are presented as means ± SD unless otherwise indicated. DBP, diastolic blood pressure; SBP, systolic blood pressure.

APPENDIX 3 Index BP Classification of 100 806 Boys Aged 3–17 Years by Age

Age, y	*n*	Normal BP at Index Visit (*n* = 79 979)	Prehypertension at Index Visit (*n* = 15 463)	BP ≥95th Percentile at Index Visit (*n* = 5364)	Children with Index BP ≥95th Percentile (*n* = 5364)		
					Repeat BP <95th Percentile (*n* = 3211)	No Repeat BP (*n* = 2025)	Hypertension (*n* = 128)
3	4664	3838 (82.3)	481 (10.3)	345 (7.4)	261 (5.6)	79 (1.7)	5 (0.11)
4	12 354	10 470 (84.8)	1105 (8.9)	779 (6.3)	509 (4.1)	258 (2.1)	12 (0.10)
5	7761	6886 (88.7)	511 (6.6)	364 (4.7)	185 (2.4)	171 (2.2)	8 (0.10)
6	5321	4744 (89.2)	330 (6.2)	247 (4.6)	118 (2.2)	124 (2.3)	5 (0.09)
7	5082	4565 (89.8)	296 (5.8)	221 (4.4)	115 (2.3)	104 (2.1)	2 (0.04)
8	5818	5152 (88.6)	353 (6.1)	313 (5.4)	158 (2.7)	154 (2.7)	1 (0.02)
9	5583	4976 (89.1)	330 (5.9)	277 (5.0)	161 (2.9)	109 (2.0)	7 (0.13)
10	5951	5338 (89.7)	365 (6.1)	248 (4.2)	146 (2.5)	101 (1.7)	1 (0.15)
11	7519	6598 (87.8)	577 (7.7)	344 (4.6)	197 (2.6)	136 (1.8)	11 (0.15)
12	6942	5774 (83.2)	822 (11.8)	346 (5.0)	204 (2.9)	133 (1.9)	9 (0.13)
13	6467	4851 (75.0)	1280 (19.8)	336 (5.2)	196 (3.0)	129 (2.0)	11 (0.17)
14	8236	5650 (68.6)	2051 (24.9)	535 (6.5)	338 (4.1)	177 (2.2)	20 (0.24)
15	7281	4567 (62.7)	2290 (31.5)	424 (5.8)	257 (3.5)	151 (2.1)	16 (0.22)
16	6191	3522 (56.9)	2348 (37.9)	321 (5.2)	201 (3.3)	109 (1.8)	11 (0.18)
17	5636	3048 (54.1)	2324 (41.2)	264 (4.7)	165 (2.9)	90 (1.6)	9 (0.16)

Data are presented as *n* (%) unless otherwise indicated.

APPENDIX 4 Index BP Classification of 98 707 Girls Aged 3–17 Years by Age

Age, y	*n*	Normal BP at Index Visit (*n* = 83 316)	Prehypertension at Index Visit (*n* = 9907)	BP ≥95th Percentile at Index Visit (*n* = 5484)	Children with Index BP ≥95th Percentile (*n* = 5484)		
					Repeat BP <95th Percentile (*n* = 3271)	No Repeat BP (*n* = 2084)	Hypertension (*n* = 129)
3	4382	3630 (82.8)	392 (9.0)	360 (8.2)	273 (6.2)	83 (1.9)	4 (0.09)
4	11 814	10 042 (85.0)	963 (8.2)	809 (6.9)	524 (4.4)	277 (2.3)	8 (0.07)
5	7494	6489 (86.6)	565 (7.5)	440 (5.9)	215 (2.9)	215 (2.9)	10 (0.13)
6	5115	4428 (86.6)	361 (7.1)	326 (6.4)	159 (3.1)	163 (3.2)	4 (0.08)
7	4844	4241 (87.6)	309 (6.4)	294 (6.1)	139 (2.9)	147 (3.0)	8 (0.17)
8	5138	4516 (87.9)	329 (6.4)	293 (5.7)	146 (2.8)	144 (2.8)	3 (0.06)
9	5339	4712 (88.3)	325 (6.1)	302 (5.7)	157 (2.9)	141 (2.6)	4 (0.07)
10	5537	4901 (88.5)	359 (6.5)	277 (5.0)	161 (2.9)	113 (2.0)	3 (0.05)
11	7670	6750 (88.0)	571 (7.4)	349 (4.6)	193 (2.5)	149 (1.9)	7 (0.09)
12	7116	6068 (85.3)	663 (9.3)	385 (5.4)	209 (2.9)	165 (2.3)	11 (0.15)
13	6477	5380 (83.1)	759 (11.7)	338 (5.2)	194 (3.0)	134 (2.1)	10 (0.15)
14	8240	6737 (81.8)	1093 (13.3)	410 (5.0)	274 (3.3)	120 (1.5)	16 (0.19)
15	7325	5935 (81.0)	1066 (14.6)	324 (4.4)	217 (3.0)	93 (1.3)	14 (0.19)
16	6244	4917 (78.8)	1054 (16.9)	273 (4.4)	186 (3.0)	72 (1.2)	15 (0.24)
17	5972	4570 (76.5)	1098 (18.4)	304 (5.1)	224 (3.8)	68 (1.1)	12 (0.20)

Data are presented as *n* (%) unless otherwise indicated.