


Under-recognition of pediatric hypertension diagnosis: Examination of 1 year of visits to community health centers

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Funding information

National Heart, Lung, and Blood Institute, Grant/Award Number: R56HL148192; National Institute on Drug Abuse, Grant/Award Number: P30DA027828

Abstract

Pediatric hypertension is associated with significant target organ damage in children and cardiovascular morbidity in adulthood. Appropriate diagnosis and management per guideline recommendations are inconsistent. In this study, we determined the proportion of missed diagnosis of hypertension and prehypertension and appropriate follow-up in pediatric patients, stratified by sex, age, race/ethnicity, and weight status. Based on the electronic health record (EHR) data from eight federally qualified health centers, among 62,982 children aged 3 to 18 years, 6233 (10%) had at least one abnormal blood pressure (BP) measurement over twelve months. Among those children whose recorded BPs met the criteria for prehypertension ($N = 6178$), 14.6% had a diagnosis in the EHR. These children were more likely to be White and have obesity compared with children who met the criteria but were not diagnosed with prehypertension. Among those who met the criteria for hypertension ($N = 55$), 41.8% had a diagnosis of hypertension in the EHR. Being diagnosed with hypertension was not associated with any examined patient characteristics. Over eleven months, 2837 children had BP \geq 95th percentile on \geq 1 visit. Only 13% had guideline-adherent follow-up within 1 month and were more likely to be older, female, and of Hispanic ethnicity or "other" race. Over six months, 2902 children had BP \geq 90th percentile on one visit. 41% had guideline-adherent follow-up within 6 months and were more likely to be older, of either White, Hispanic, Asian race, or Hispanic ethnicity. In a community-based setting, pediatric hypertension and prehypertension were persistently underdiagnosed with low adherence to recommended follow-up.

1 | INTRODUCTION

The prevalence of pediatric hypertension (PH) is estimated around 4% both in the United States and internationally.^{1,2} PH increases odds of developing adult hypertension and metabolic syndrome, and it is estimated that almost 10% of hypertension in adults could

be prevented if high blood pressures in childhood were recognized and treated.³⁻⁵ Apart from contributing to adult morbidity, PH is associated with target organ damage including left ventricular hypertrophy, greater carotid intima-media thickness (as a marker of atherosclerosis), proteinuria (a marker of kidney damage), and decreased executive functioning in children.⁶⁻⁹

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Hypertension is defined simply in adults as elevated blood pressure (EBP: >120-129 mmHg systolic and < 80 mmHg diastolic) or hypertension (\geq 130 mmHg systolic and \geq 80 mmHg diastolic). The 2004 4th Report (4thR) defines abnormal blood pressure as \geq 90th percentile (%ile) (for age, height, and gender (AGH)), prehypertension as \geq 90th %ile but < 95th %ile (AGH), and hypertension as \geq 95th %ile (AGH) at 3 separate visits. For adolescents, abnormal blood pressure is > 120/80 (AGH).^{10,11} As such, accurate diagnosis depends on providers' knowledge of reference values, as well as appropriate tools and techniques required for measurement, and is compounded by the insufficient time available in fast-paced clinics.^{10,12-14} Unsurprisingly, studies consistently demonstrate underdiagnosis of PH.^{13,14} Understanding the characteristics that place particular children at higher risk of having hypertension may assist clinicians in appropriate diagnosis and management. For example, predictors of PH include a history of prematurity, being overweight or obese, of male sex, older age (adolescent compared with younger children), race and ethnicity (African American, Latino/Hispanic), having a higher salt intake, and a history of familial hypertension.^{2,15-18} Most studies of PH have examined associations with these demographic factors for ages 8 and up, but scant data exist for younger age-groups.^{15,19} Even fewer studies report actual diagnosis provided by physicians or the rates of follow-up appointment attendance per the 2017 CPG or 4thR specially stratified according to demographics.^{13,20-22}

The purpose of this study was to describe the proportion of appropriate diagnosis of PH and prehypertension by clinicians serving a diverse pediatric population from community-based primary care settings. Compared to previous studies, we examined child demographic factors associated with appropriate PH and prehypertension diagnoses and 4thR directed follow-up appointments among children age \geq 3 years and \leq 18 years with at least one abnormal BP reading. Our objectives were to describe (overall and by categories of age, sex, race, and ethnicity as well as weight status) 1) the proportion of children who were appropriately diagnosed with PH or prehypertension by International Classification of Diseases, Tenth Revision (ICD-10) codes, in the electronic health record (EHR) per the 4thR; and 2) the proportion of children with abnormal BP who had a follow-up visit per 4thR recommendations (ie, within 1 month for BPs \geq 95th %ile, within 6 months for BPs \geq 90th %ile).

2 | METHODS

2.1 | Study design

A cross-sectional retrospective review of 1 year of clinical data from the EHR.

2.2 | Setting

All clinical data were retrieved from the EHR of community-based ambulatory health centers in Chicago for clinical visits occurring between December 31, 2016, and December 31, 2017. The population

is diverse, as the catchment area for the health centers encompasses all 77 Chicago neighborhoods. A large proportion of families have incomes below the federal poverty level. IRB approval was obtained from the Northwestern University.

Data from the year prior to implementing the 2017 CPG into clinical guidance and the EHR were used for this study. This approach was taken to capture a time period in which the 4thR had been in place over several years and would have been familiar to clinicians. Moreover, the clinicians would have had several years of access to and experience with technology tools (eg, EHR decision support) to support PH/prehypertension management in accordance with those guidelines.

2.3 | Participants

Inclusion criteria. Electronic health data of all patients were reviewed. Children, aged \geq 3 years and \leq 18 years, who had at least one visit with systolic or diastolic blood pressure readings that were \geq 90th %ile for age, sex, and height were identified for further analysis.

Exclusion criteria. Patients who were pregnant or who had diagnoses of neonatal or pulmonary hypertension or hypertensive disease complicating pregnancy, childbirth, or the postpartum period were excluded.

2.4 | Measures

2.4.1 | Patient demographics

Data were extracted from an enterprise data warehouse housing the EHR from eight community health center organizations, each with multiple clinics. No personal identifying information (eg, date of birth, medical record number) was extracted. The validation process included a review of 10% of the patient-level data from each of the health centers (ie, variables included in the dataset were cross-referenced against the individual patient's EHR to ensure vital signs aligned with the clinical information in the chart). Patient characteristics, including sex at birth, age, race, and ethnicity, as well as BMI %iles, were extracted. Sex was either male or female. Race included White, Black, Hispanic, Asian, other (when it was entered as such), and unknown (not entered). Ethnicity included Hispanic/Latino, not Hispanic/Latino, or unknown (not entered). Hispanic was entered as both race and ethnicity in the EHR and therefore is reported in both categories. Age was categorized as \geq 3-6 years, 7-11 years, and \geq 12-18 years. Weight status categories included underweight (<5th BMI %ile), normal weight (5-85th BMI %ile), overweight (85th-95th BMI %iles), and obese (>95th BMI %ile) per CDC guidelines.²³

2.4.2 | Blood pressure readings

Blood pressure %iles were calculated in the EHR using the normative data from the 4thR.¹⁰ PH was defined as a systolic and/or diastolic BP \geq 95th %ile (for age, sex, and height) persistent on \geq 3 visits.¹⁰

Diagnosis of PH was defined as having an ICD-10 code of I10 (Essential Hypertension) in the EHR. **Prehypertension** was defined as systolic and/or diastolic BP \geq 90th %ile to $<$ 95th %ile (for age, sex, and height) at any visit for children $<$ 13 years. In children $>$ 13 years, prehypertension was defined as BP $>$ 120/80 to $<$ 95th %ile. Diagnosis of prehypertension was defined as having an ICD-10 code of R03.0 (elevated blood pressure reading without diagnosis of hypertension).

Blood pressure is defined as abnormal if $>$ 90th percentile (for age, sex, and height) or $>$ 120/80 for children aged $>$ 13 years, on at least one visit. We report abnormal BP and BP $>$ 95th %tile on at least 1 visit, as well as abnormal BP on at least 3 visits to test whether certain patient characteristics were more likely to be associated with one category or the other.

2.4.3 | Follow-up visits

We assessed the proportion of children with abnormal BP who appropriately attended a follow-up visit per 4thR.^{10,12} Per the 4thR, there are different criteria for follow-up depending on BP percentiles. For children with BP readings \geq 95th %ile on one visit, the guidelines recommend follow-up within 2 weeks; thus, the analysis was limited to those patients with measurements between December 2016 and November 2017 (to allow for a 1-month follow-up period). For children with BP readings \geq 90th %ile on one visit, the guidelines recommend follow-up within 6 months; thus, the analysis was limited to those patients with measurements between December 2016 and June 2017 (to allow for a 6-month follow-up period).

2.5 | Statistical analyses

Because the purpose of the study was to determine the proportion of accurate diagnoses, proportions will be reported with the numerator of accurately diagnosed cases over the denominator of unique patients seen in the specified time period. Number (percent) for categorical variables was calculated to describe the distribution of demographic and clinical characteristics of participants. Fisher's exact test was performed to compare differences across the categories of sex, age, race, ethnicity, and weight status, in the proportion of children who (a) were appropriately diagnosed with either PH or EBP by a provider using ICD-10 codes and (b) attended a follow-up visit within the guideline-directed time frame. A 2-tailed p -value $<$ 0.05 was considered statistically significant. All analyses were performed using Stata 14 (StataCorp).

3 | RESULTS

3.1 | Sample characteristics

There were 62,982 unique patient visits among children aged \geq 3 to \leq 18 years between 12/31/2016 and 12/31/2017. We identified 6233 children who had an abnormal BP measurement at \geq 1 visit

TABLE 1 Sample characteristics of children aged 3-18 years with abnormal blood pressures (BP \geq 90th percentile) on \geq 1 visit from December 31, 2016, through December 31, 2017. $N = 6233$

Variable	N (%)
Sex	
Male	3105 (49.8)
Female	3128 (50.2)
Age (category)	
\leq 6 years	2564 (41.1)
7-11 years	1547 (24.8)
\geq 12 years	2123 (34.1)
Race	
White	3370 (54.1)
Black	1598 (25.6)
Hispanic ^a	881 (14.1)
Asian	160 (2.6)
Other	27 (0.4)
Unknown	198 (3.2)
Ethnicity: Hispanic/Latino	
Yes	3927 (63)
No	2163 (34.7)
Unknown	144 (2.3)
Weight status ^b	
Underweight	103 (1.7)
Normal weight	2296 (36.8)
Overweight	942 (15.1)
Obese	2893 (46.4)

^aThe race category of "Hispanic" was included when it was entered as the Race in the electronic health record.

^bWeight status defined by percentiles: underweight ($<$ 5th percentile), normal weight (5-85th percentiles), overweight (85-95th percentiles), and obese (\geq 95th percentile)

(Table 1). The sample included equal proportions of male and female children. Most children were under 6 years of age (41%), were of White race (54%), and of Hispanic ethnicity (63%). The largest proportion of children had a BMI in the obese range (46%).

3.2 | Pediatric Hypertension Diagnosis

Among the 62,983 records reviewed, 55 children (0.1%) met the criteria for hypertension. Twenty-three of the 55 (41.8%) had an ICD-10 code for hypertension recorded in the EHR (Table 2). Being appropriately diagnosed was not associated with age ($p = .10$), sex ($p = .07$), race ($p = .91$), or ethnicity ($p = .42$) or weight status ($p = .69$) (Table 2).

3.3 | Prehypertension Diagnosis

Overall prevalence of prehypertension was 10% (6178/62982). Among 6178 children with prehypertension, 919 (14.6%) had an

ICD-10 code for prehypertension in the EHR (Table 2). Being appropriately diagnosed with prehypertension, compared to meeting criteria without diagnosis, was associated with White race ($p = .049$) and having a BMI in the obese range ($p < .001$) (Table 2).

3.4 | Follow-up visits

6233 children with an abnormal BP in the EHR were analyzed for guideline adherent follow-up visits. For BP > 95th percentile at

first visit, appropriate follow-up should be within one month. Out of 2837 children with BP readings \geq 95th %ile between December 2016 and November 2017, 378 (13.3%) were seen for a follow-up visit within the guideline specified one-month period (Table 3). Patient characteristics associated with a greater likelihood of appropriate follow-up were older age (≥ 12 years; $p < .001$), female sex ($p = .047$), "other" race ($p = .045$), and Hispanic ethnicity ($p = .006$), but not weight status ($p = .341$). Asian race and "unspecified" race were the least likely to have a follow-up within the specified time ($p = .045$).

Variables	Pediatric Hypertension ^a		<i>p</i> -value ^e	Prehypertension ^b		<i>p</i> -value ^e
	Cases ^c N (%)	Diagnosed ^d N (%)		Cases ^c N (%)	Diagnosed ^d N (%)	
Total	55 (8.8)	23 (41.8)		6178 (99.1)	919 (14.6)	
Sex			.07			.1
Male	23 (41.8)	13 (56.5)		3083 (49.8)	465 (15.1)	
Female	32 (58.2)	10 (31.3)		3095 (50.2)	454 (14.7)	
Age (category)			.10			.67
≤ 6 years	12 (21.8)	3 (25)		2552 (41.1)	276 (10.8)	
7-11 years	8 (14.5)	6 (75)		1539 (24.8)	267 (17.3)	
≥ 12 years	35 (63.6)	14 (40)		2087 (34.0)	376 (18)	
Race			.91			.049
White	34 (61.8)	15 (44.1)		3336 (54.1)	542 (16.1)	
Black	5 (9.1)	2 (40)		1593 (25.6)	214 (13.4)	
Hispanic	13 (23.6)	6 (46.2)		867 (14.1)	117 (13.5)	
Asian	1 (1.8)	0 (0)		159 (2.6)	18 (11.3)	
Other	0 (0)	0 (0)		27 (0.44)	3 (11.1)	
Unknown	2 (3.6)	0 (0)		196 (3.2)	25 (12.8)	
Ethnicity:			.42			.30
Hispanic/Latino						
Yes	41 (74.5)	19 (46.3)		3885 (63.0)	599 (15.4)	
No	13 (23.6)	4 (30.8)		2150 (34.7)	300 (14)	
Unknown	1 (1.8)	0 (0)		143 (2.3)	20 (14)	
Weight Category			.69			<.001
<5%ile	0 (0)	0 (0)		103 (1.7)	13 (12.6)	
5 < 85%ile	11 (20)	6 (54.5)		2284 (36.6)	266 (11.6)	
85 < 95%ile	5 (9)	2 (40)		937 (15.0)	130 (13.9)	
≥ 95 %ile	39 (70.9)	15 (38.5)		2854 (45.8)	510 (17.9)	

^aPediatric Hypertension: blood pressure \geq 95th percentile at > 3 visits.

^bPrehypertension: blood pressure \geq 90th percentile at > 1 visit.

^cCases: Patients who met criteria for either pediatric hypertension or prehypertension. In the columns, "Cases," the % indicates the proportion of the column total (first line), for example, 55 is 8.8% of all patients with an abnormal BP on > 1 visit and 41.8% of PH cases were male.

^dDiagnosed: Patients given ICD-10 code for diagnosis of either pediatric hypertension or prehypertension. In the columns, "Diagnosed," the % indicates the proportion of the row value, for example, out of the 23 males who had PH, 56.5% were diagnosed.

^eThe *p*-values indicate where there are differences in who received an appropriate ICD-10 code within the category (eg, male vs. female proportions who received an appropriate ICD-10 diagnosis, within the category of Sex).

TABLE 2 Children with high blood pressure readings who are appropriately diagnosed with pediatric hypertension or prehypertension, by demographic factors

For BP > 90th percentile at first visit, follow-up was within six months. Out of 2902 children with BP readings \geq 90th %ile between December 2016 and June 2017, 1190 (41%) were seen for a follow-up visit within the guideline specified six-month period (Table 3). Patient characteristics associated with a greater likelihood of follow-up were older age (≥ 7 years; $p < .001$), White, Hispanic, and Asian race ($p = .042$), and Hispanic ethnicity ($p = .036$), but not weight status ($p = .304$).

4 | DISCUSSION

In this study, we found persistent underdiagnosis and inadequate follow-up of PH and prehypertension in children aged 3-18 years from a diverse community setting. We found a low number of actual

hypertensive cases ($N = 55$). This is likely underestimated since not all patients had a guideline-adherent follow-up visit (13.3% within a month of first elevated BP \geq 95th %ile and 41% within six months of first elevated BP \geq 90th %ile), thereby missing a significant proportion of patients who could have had prehypertension or hypertension. However, even for those children that had the requisite number of follow-ups to make a diagnosis, more than half (58.2%) went undiagnosed.

Under-recognition of hypertension is prevalent in adults (60%-70% appropriately diagnosed) but is worse in children (20%-30% appropriately diagnosed).^{13,20,21,24} Multiple factors contribute to this, including the complicated criteria present in the 4thR, intricate BP measurement techniques for children and infants, poor training of support staff who obtain and interpret BP readings, workflow issues, inability to identify next steps in BP management,

TABLE 3 Children with elevated blood pressure readings who attended a follow-up visit per 2004 4th Report recommendations, by demographic and biometric factors

Variables	BP \geq 95th percentile ^a N (%)	Attended follow-up (30 days) ^b , N (%)	<i>p</i> -value ^c	BP \geq 90th percentile ^a N (%)	Attended follow-up (6 months) ^b , N (%)	<i>p</i> -value ^c
Total	2,837	378 (13.3)		2,902	1190 (41.0)	
Sex			.047			.450
Male	1,412 (49.8)	170 (12)		1,454 (50.1)	586 (40.3)	
Female	1,425 (50.2)	208 (14.6)		1,448 (49.9)	604 (41.7)	
Age (category)			<.001			<.001
≤ 6 years	1,137 (40.1)	114 (10)		1,185 (40.8)	431 (36.4)	
7-11 years	687 (24.2)	67 (9.8)		684 (23.6)	283 (41.4)	
≥ 12 years	1,013 (35.7)	197 (19.4)		1,033 (35.6)	476 (46.1)	
Race			.045			.042
White	1,509 (53.2)	221 (14.6)		1,564 (53.9)	673 (43)	
Black	754 (26.6)	83 (11)		745 (25.7)	268 (36)	
Hispanic	405 (14.3)	58 (14.3)		416 (14.3)	178 (42.8)	
Asian	71 (2.5)	7 (9.9)		76 (2.6)	32 (42.1)	
Other	13 (0.5)	3 (23.1)		17 (0.6)	6 (35.3)	
Unknown	85 (3)	6 (7.1)		84 (2.9)	33 (39.3)	
Ethnicity: Hispanic/Latino			.006			.036
Yes	1,754 (61.8)	261 (14.9)		1,815 (62.5)	777 (42.8)	
No	1,024 (36.1)	109 (10.6)		1,014 (34.9)	384 (37.9)	
Unknown	59 (2.1)	8 (13.6)		73 (2.5)	29 (39.7)	
Weight status			.341			.304
Underweight	46 (1.6)	4 (8.7)		37 (1.3)	11 (29.7)	
Normal weight	985 (34.7)	118 (12)		1,025 (35.3)	406 (39.6)	
Overweight	421 (14.8)	60 (14.3)		403 (13.9)	166 (41.2)	
Obese	1,385 (48.8)	196 (14.2)		1,437 (49.5)	607 (42.2)	

^aThe % indicates the proportion of the column total (first line).

^bThe % indicates the proportion of the row value.

^cThe *p*-values indicate where there are differences in who attended appropriate follow-up within the category (eg, male vs. female proportions who attended appropriate follow-up, within the category of sex).

and poor appreciation of primary hypertension and its effects in children.^{14,25-27} Daley et al²² reported 20% of children attended appropriate follow-up for elevated BP readings which is lower than our study findings of 41%, this improvement may have been secondary to increased time exposure to the 4thR recommendations and better utilization in the EHR. They further described only 1.4% of those were found to have persistently elevated BP at consecutive visits which was very similar to our study findings of 1.9%.

The 2017 CPG were formulated to improve recognition of PH and abnormal BP in children, with revised BP tables with lower abnormal cutoff values (including normative data from normal weight children), simplified BP screening tables, simplified definition of PH and abnormal BP in children aged ≥ 13 years, the addition of specific height values rather than height percentiles, and detailed directions on measuring BPs in children.¹² The change from the 4thR to the 2017 CPG resulted in a higher prevalence of PH and EBP/prehypertension in children, but to our knowledge no study to date reports on improvement in diagnoses rates.²⁸

The demographic and biometric associations in our study (improved prehypertension diagnosis rates in children who were White, Hispanic, or Asian race and Hispanic ethnicity, and with a BMI in the obese range, and increased likelihood of follow-up in older, female, and non-Black ethnicities/races) are mostly supported by current literature. Although age was not significantly associated with a diagnosis in our study, it was associated with follow-up rates. Providers are more likely to diagnose PH if BP values exceeded 120/80 mmHg, and since such values are more likely to be present in older children, this is a probable reason that older children are more frequently diagnosed with PH and have timely follow-up appointments.²⁰ Despite increased prevalence of PH in Black race, our study found lower likelihood of diagnosis in such children.^{2,19,28} Studies have shown that physician implicit bias can negatively impact recognition of disease in minorities.²⁹ Using EHR-based software has been shown to improve rates of diagnosis and management of hypertension and mitigate effect of racial bias present in providers.³⁰ Evidence on obesity is divided, with some studies reporting greater recognition of abnormal BP in children with higher BMI and others that found no association.^{2,17,20,21}

In addition to the newer 2017 CPG, additional interventions are required to improve management of PH. EHR-based tools and population health tools can be utilized to improve screening, and provide referral alerts and management directions.³¹ Simplified and interactive training tools may improve education for high turnover medical staff and be an easy review resource for providers.^{14,32} Since guidelines for both hypertension and obesity recommend frequent follow-up, this intersection offers an opportunity to improve both obesity and hypertension follow-up simultaneously in children.^{12,33}

4.1 | Strengths/limitations

To our knowledge, this is the first study to report follow-up stratified based on demographics. This study used data from multiple community health centers that serve a diverse, urban population

of children, which may limit the generalizability. Compared to previous studies, we focused on the population of high-risk children (≥ 1 elevated BP reading) and assessed 4thR concordant diagnosis of PH and prehypertension and follow-up appointment attendance. The true prevalence of hypertension and prehypertension could not be calculated due to the low follow-up (only 13% and 41%, respectively). Furthermore, we only reported follow-up visits for specific time periods (1 month and 6 months), thereby excluding other follow-up visits that would have been done outside of the 4thR recommended time periods. This is likely underestimating overall prevalence and overall follow-up rates. By focusing on children with abnormal BP, we were able to delineate specific disparities that exist in the diagnosis and management of at-risk youth. Using ICD-10 codes to assess provider recognition of PH and prehypertension may underreport actual diagnosis and management (eg, if providers conducted repeated manual readings or made appropriate referrals to specialists). Last, the accuracy of BP measurements is not known.

4.2 | Conclusion

This study found that PH and prehypertension were persistently underdiagnosed and follow-up was inadequate among diverse pediatric patients seen in community health centers. Certain demographics were associated with improved diagnostic rates (White race, obesity) and 4thR adherent follow-up appointments (older age, female sex, non-Black race). Since hypertension can cause target organ damage in children and cardiovascular morbidity in adults, timely diagnosis and management can have significant long-term benefits. In all, these findings indicate a need for tools and training to support guideline-concordant diagnosis and management of hypertension and abnormal BP among children and adolescents. Approaches to consider may include developing health information technology tools to assist providers in the care of this high-risk population and targeted workforce training on various steps in diagnosis and managing blood pressure in children.

ACKNOWLEDGMENTS

This study was supported by grant R56HL148192 from the National Heart, Lung, and Blood Institute of the National Institutes of Health, awarded to Justin Smith. Additional support was provided by grant P30DA027828 from the National Institute on Drug Abuse, awarded to C. Hendricks Brown. The opinions expressed herein are the views of the authors and do not necessarily reflect the official policy or position of the, the National Heart, Lung, and Blood Institute, the National Institute on Drug Abuse, or any other part of the US Department of Health and Human Services.

CONFLICTS OF INTEREST

AM, YGT, AJC, CBL, and JDS have none to declare. NM and RP receive salary support from AllianceChicago. Northwestern Medicine

is affiliated with Northwestern University, Feinberg Medical School and AllianceChicago.

DATA SHARING

The data from this study are not available.

INFORMATION ON AUTHOR ACCESS TO DATA

AM, NM, RP, YGT, CBL, and JDS had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

AUTHOR CONTRIBUTIONS

AM, NM, CBL, and JDS conceived of and designed the study. RP completed the data request and extraction and validated data prior to delivery. YGT conducted the analysis. All authors contributed to interpreting the results of the analyses. AM led the preparation of the manuscript. NM, YGT, AJC, CBL, RP, and JDS collaborated in drafting the manuscript. All authors read, edited, and approved the final version of the manuscript and are in agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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How to cite this article: Moin A, Mohanty N, Tedla YG, et al. Under-recognition of pediatric hypertension diagnosis: Examination of 1 year of visits to community health centers. *J Clin Hypertens.* 2021;23:257-264. <https://doi.org/10.1111/jch.14148>