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Performance of blood pressure to height ratio at a single screening visit for the identification of hypertension in children

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Abstract

Background: The diagnosis of hypertension in children is difficult because of the multiple sex-, age-, and height-specific thresholds to define elevated blood pressure (BP). Blood pressure to height ratio (BPHR) has been proposed to facilitate the identification of elevated BP in children.

Objective: We assessed the performance of BPHR at a single screening visit to identify children with hypertension, that is, sustained elevated BP.

Method: In a school-based study conducted in Switzerland, BP was measured at up to three visits in 5207 children. Children had hypertension if BP was elevated at the three visits. Sensitivity, specificity, negative and positive predictive values (PV) for the identification of hypertension were assessed for different thresholds of BPHR. The ability of BPHR at a single screening visit to discriminate children with and without hypertension was evaluated with receiver operating characteristic (ROC) curve analyses.

Results: The prevalence of systolic/diastolic hypertension was 2.2%. Systolic BPHR had a better performance to identify hypertension compared to diastolic BPHR (area under the ROC curve: 0.95 vs. 0.84). The highest performance was obtained with a systolic BPHR threshold set at 0.80 [mmHg/cm] (sensitivity: 98%; specificity: 85%; positive PV: 12%; negative PV: 100%) and a diastolic BPHR threshold set at 0.45 [mmHg/cm] (sensitivity: 79%; specificity: 70%; positive PV: 5%; negative PV: 99%). The positive PV was higher among tall or overweight children.

Conclusion: BPHR at a single screening visit had a high performance to identify hypertension in children, although the low prevalence of hypertension led to a low positive PV.

Key words: hypertension; children; screening; blood-pressure-to-height-ratio

Introduction

Hypertension is a major cardiovascular risk factor in adults and a major cause of morbidity and mortality worldwide (1). Children and adolescents with hypertension are at increased risk of hypertension later in life (2–4) and intermediate markers of hypertensive target organ damage, such as left ventricular hypertrophy and thickening of the carotid vessel wall, have been found in children and adolescents with elevated blood pressure (3,4).

While universal BP screening in children and adolescent has been recommended (5,6), its utility is vividly debated (4,7). One major challenge of screening in children is that identification of hypertension is difficult at that age (4). Contrary to adults, elevated BP in children is not defined based on the relationship between BP and outcomes later in life such as cardiovascular diseases or death (8). In children, the normal level for BP is based on the distribution of BP within the population and depends on the child's sex-, age-, and height-percentile. Consequently, complex tables of normative BP values with numerous sex-, age-, and height-percentile specific thresholds are used. User-friendly tools to facilitate the identification of hypertension in children would help health professionals in their screening activities.

In 2011, Lu et al. evaluated for the first time the performance of the blood pressure-to-height ratio (BPHR) for identifying elevated BP in Chinese adolescents. They found that BPHR was an accurate index for the identification of elevated BP in adolescents (9). Other studies have confirmed the high performance of BPHR to identify elevated BP in children and adolescents (10-14) **(Table1)**. Nevertheless, only one study has evaluated the performance of BPHR to identify 5 hypertension, that is, sustained elevated BP at successive visits, and this study was conducted in

Chinese children aged 7 to 12 years old (14). Furthermore, the optimal systolic and diastolic BPHR thresholds remain to be determined. Therefore, using data from a large school-based study of Swiss children aged 10-14 years having BP measured at up to three visits (8,15,16), we assessed the performance of various thresholds of BPHR at a single screening visit to identify hypertension.

Method

Study population and measurement methods

We conducted a post hoc analysis of data collected among 5207 children in the 6th grade from all schools of the canton de Vaud (Switzerland) in 2005/06 (8,15,16). The primary goal of this study was to estimate the prevalence of hypertension in Swiss children. The study was approved by the ethics research committee of the Faculty of Biology and Medicine of the University of Lausanne. Consent was sought from directors of all schools. Signed consent of one of the parents and of the child were obtained.

At the initial (screening) visit, weight, height, and BP were measured. Children were measured without shoes and in light garments in a quiet and tempered room by trained clinical officers. Weight and height were measured with precision electronic scales (to the nearest 0.1 kg) and fixed stadiometers (to the nearest 0.1 cm). BP was measured on the right arm, after a rest of at least 3 min, with the child in a seated position (to the nearest 1 mmHg). The mid-arm circumference was measured and the cuff width adapted accordingly. BP was measured with a clinically validated oscillometric device (Omron M6; Omron Healthcare Europe BV, Hoofddorp, The Netherlands).

Three BP measurements were taken at 1-minute intervals. The average of the last two of the three BP readings was used for the analyses. Elevated BP was based on the American reference data (5) and was defined for systolic or diastolic ≥95th sex-specific, age-specific and height-specific percentiles. Sex-specific and age-specific percentiles of height (which are needed to determine BP thresholds for elevated BP) were derived from the U.S. Centers for Disease Control and Prevention (CDC) growth charts. If children had elevated BP at the initial visit, BP was measured on up to two additional visits, separated by at least one week and using the same BP measurement method. Children with sustained elevated BP at the three visits had hypertension.

Statistical analyses

Systolic BPHR and diastolic BPHR [mmHg/cm] were computed as the ratio of systolic or diastolic BP [mmHg] at initial (screening) visit on height [cm]. Sensitivity, specificity, positive (PPV), and negative predictive values (NPV) of BPHR above given thresholds (0.70, 0.75, 0.80, 0.85, 0.90 for systolic BPHR; 0.40, 0.45, 0.50, 0.55, 0.60 for diastolic BPHR) for the identification of hypertension were computed. Further, we assessed the ability of BPHR to discriminate children with and without hypertension with a receiver operating characteristic (ROC) curve analysis, also known as the C statistic (17,18). The area under the ROC curve (AUC) statistic represents the probability of correctly classifying children with and without hypertension. AUC was computed for systolic and diastolic BPHR. The AUC ranges from 0.5 (random discrimination) to 1.0 (perfect discrimination) and values of 0.8 and above are traditionally considered as indicating a strong discrimination power. Statistical difference between AUC for systolic BP and diastolic BP were tested using the Stata® comproc command (19). Further, stratified analyses were conducted by sex (boys vs. girls), by height categories (tertiles of height z-scores), and by body weight categories (normal weight vs. overweight/obesity, using the IOTF definition (20)).

Results

Characteristics of participants are shown in **Table 2**. Of the 6873 eligible children, 5207 participated (participation rate: 76%; 2621 boys, 2586 girls; age range: 10.1-14.9 years). The prevalence of systolic/diastolic, systolic, and diastolic hypertension was 2.2%, 2.1%, and 0.4%, respectively. The prevalence of hypertension was similar in boys and girls. Systolic and diastolic BPHR had a normal distribution. The correlations between systolic BPHR and the z-score of systolic BP and between diastolic BPHR and the z-score of diastolic BP at the initial visit was 0.94 ($p<0.001$) and 0.96 ($p<0.001$), respectively.

Sensitivity, specificity, NPV, and PPV of systolic and diastolic BPHR to identify hypertension are shown in **Tables 3 and 4**, respectively. Proportions of children with systolic BPHR≥0.70, 0.75, 0.80, 0.85, and 0.90 were 70.4%, 39.2%, 16.2%, 4.8%, and 1.3%, respectively. The performance of systolic BPHR to identify children with systolic/diastolic hypertension and children with systolic hypertension was similar **(Table 3)**. With systolic BPHR thresholds set at 0.70 or 0.75 [mmHg/cm], the sensitivity to identify systolic/diastolic hypertension was high but the specificity was low. When the threshold was set at 0.80 [mmHg/cm], the sensitivity remained elevated (92%), the specificity reached 85%, and the PPV was 12%. At higher thresholds, the sensitivity of systolic

BPHR decreased substantially. At any threshold, NPV was high (98% or more). Similar results were obtained when analyses were conducted separately in boys and girls **(appendix Tables A2)**. The sensitivity and specificity were similar when analyses were conducted separately by height categories or by body weight categories. Because the prevalence of hypertension increased with height and body weight, the PPV was higher among tall children **(appendix Tables A5)** and among overweight/obese children **(appendix Tables A8)**.

Proportions of children with diastolic BPHR≥0.40, 0.45, 0.50, 0.55, and 0.60 were 72.8%, 31.5%, 7.6%, 1.1%, and 0.1%, respectively. Overall, the performance of diastolic BPHR was weaker compared to the performance of systolic BPHR ($p<0.001$). The performance of diastolic BPHR to identify children with systolic/diastolic hypertension and children with diastolic hypertension was similar **(Table 4)**. With a diastolic BPHR set at 0.40 [mmHg/cm], the sensitivity to identify systolic/diastolic hypertension was high but the specificity was low. When the threshold was set at 0.45 [mmHg/cm], the sensitivity decreased slightly (79%), the specificity reached 70%, and the PPV reached 5%. At a threshold of 0.50 [mmHg/cm], the specificity and PPV was better but the sensitivity decreased substantially. At any threshold, NPV was high, that is, 98% or more. Similar results were obtained when analyses were conducted separately in boys and girls **(appendix Tables A3)**. The sensitivity and specificity were similar when analyses were conducted separately by height categories or by body weight categories. Because the prevalence of hypertension increased with height and body weight, the PPV was higher among tall children **(appendix Tables A6)** and among overweight/obese children **(appendix Tables A9)**.

Figure 1 & Table 5 show the results of the ROC analyses assessing the discriminative power of systolic and diastolic BPHR for hypertension. On a continuous scale, the AUC of systolic BPHR and diastolic BPHR were both high (>0.80) for systolic/diastolic hypertension **(Figure 1)**. The power of systolic BPHR to discriminate children with or without systolic/diastolic hypertension was higher compared with the power of diastolic BPHR. For systolic BPHR, the AUC was at a maximum when the threshold was set at 0.80 [mmHg] for systolic/diastolic hypertension as well as systolic hypertension **(Table 5)**. For diastolic BPHR, the AUC reached a maximum when the threshold was set at 0.45 [mmHg/cm]. Similar results were obtained when analyses were conducted separately by sex **(appendix Tables A4)**, by height categories **(appendix Table A7)**, and by body weight categories **(appendix Table A10)**, respectively.

Discussion

Our study shows that the performance of BPHR at a single screening visit to identify children with hypertension was high. Systolic BPHR had a better performance to identify hypertension compared to diastolic BPHR. The highest performance to identify children with systolic/diastolic hypertension was obtained with a systolic BPHR threshold at 0.80 [mmHg/cm] and a diastolic BPHR threshold at 0.45 [mmHg/cm]. While the performance did not differ between boys and girls, the PPV was higher among tall or overweight children.

Our results are consistent with other studies having shown the high performance of BPHR to identify elevated BP **(Table 1)** (9-14)]. In these studies, the discriminative power of systolic BPHR for the identification of elevated BP was higher compared with diastolic BPHR, which is also consistent with our observations. Only one of these studies evaluated the performance of BPHR to identify children with hypertension (9), that is, sustained elevated BP. This study was conducted among Chinese children aged 7 to 12 years. Our study was conducted in older children from a European country but we found similar performance for BPHR to identify hypertension. Furthermore, in previous studies, the authors determined the “optimal” BPHR cutoff based only on the statistical performance for the identification of elevated BP or hypertension. We have rather tried to identify the optimal cutoff for BPHR based on both clinical and statistical considerations. Therefore, the thresholds we have identified for systolic and diastolic BPHR (0.80 [mmHg/cm] and 0.45 [mmHg/cm], respectively) have a more direct potential clinical utility.

One question is indeed how BPHR could be used in practice. One possibility is schematized in the **Figure 2**. At the initial screening visit, the clinician measures BP, and height, as usual and computes BPHR. If systolic and diastolic BPHR are below the proposed thresholds, there is no need to estimate the exact BP percentile and no further BP measures at other visits are needed. For the other children, i.e., with elevated systolic or diastolic BPHR, the determination of the exact BP percentile is necessary and additional BP measurements at separated visits are needed if the BP is at or above the 95th percentile. A key premise of this approach is that, in most cases, BPHR will not be elevated and the clinician will not have to determine the exact sex-, age-, and height-specific BP percentile: the clinicians can gain times and prevent errors of BP status misclassification.

One major limitation of our study is the narrow age range of the children examined. Previous studies have shown that BPHR had a high performance at various ages to identify elevated BP. However, some studies suggest that the optimal BPHR cut-off depends on the age of the children, with the optimal cutoff maybe lower in younger children compared to older children (9-14). This study had others limitations. It was conducted in one region of Switzerland and our findings may not necessarily apply to other populations. In particular, performance could be different in populations with higher prevalence of overweight and obesity, hence of hypertension, or in populations with substantially different average heights. Some children declined participation, which may include children with hypertension: this could result in a selection bias with an underestimation of the prevalence of hypertension, leading to an underestimation of the positive predictive value of BPHR and, possibly, to a biased estimate of sensitivity. We have taken account only of children with sustained elevated BP at or above the 95^{th} percentile. Other studies have shown the high performance of BPHR to identify children with BP at or above the 90^{th} percentile, that is, BP in the prehypertension range (10). The study had several strengths. It was based on a large and school-based sample. Further, we used a standard definition of hypertension, based on three visits, and with BP measured by a trained staff using a clinically validated device along a strict and predefined protocol.

In conclusion, BPHR has a strong discrimination power to identify children with or without hypertension in Swiss children aged 10 to 14 years old. Further studies in other age ranges and other populations should be conducted to evaluate the performance of BPHR to identify children with hypertension and whether BPHR can help to identify hypertension in children in clinical practice.

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Table 1: Studies reporting blood-pressure-to-height-ratio (BPHR) to identify elevated blood pressure (BP). Elevated BP was defined in each study according to the recommendations of the 2004 National High Blood Pressure Education Program Working Group (5). All studies had a cross-sectional design and were conducted in non-clinical settings.

Study publication	Study year	N	Sample	Age [years]	BP measurement method	Cutoff values for BPHR [years]	Performances
Q. Lu & al. Journal of Human Hypertension. 2011 (9)	2006	3136	Population-based study of healthy Han adolescents, China	13-17	Auscultatory method. 3 consecutive BP measures at 1 visit. Mean BP: average of the 3 measures	SBPHR: 0.75 in boys; 0.78 in girls DBPHR:0.48 in boys; 0.51 in girls	SBPHR: Sensitivity 98.6% in boys; 98.4% in girls. Specificity 93.7% in boys; 97.9% in girls DBPHR: Sensitivity 100% in boys; 97.6% in girls. Specificity 94.3% in boys; 95.4 % in girls
C. Ejike & al. Italian Journal of Pediatrics. 2011 (10)	2007	1173	Data from healthy school children in Kogi State and in Umuahia, Abia State, Nigeria	11–17	Oscillometric method. 3 consecutive BP measures at 1 visit. Mean BP: average of the last 2 measures	SBPHR: 0.75 in boys; 0.77 in girls DBPHR:0.51 in boys; 0.50 in girls	SBPHR: Sensitivity 98.2% in boys; 98.6% in girls. Specificity 95.6% in boys; 96.3% in girls. DBPHR: Sensitivity 100% in boys; 100% girls. Specificity 99.8% in boys; 99.1% in girls
F. Rabbia & al. Journal of Human Hypertension. 2011 (11)	Not reported	1413	Students of public junior high schools, Turin, Italy	12–15	Auscultatory method. 3 consecutive BP measures at 1 visit. Mean BP: average of the 3 measures	SBPHR: 0.75 in boys; 0.78 in girls DBPHR: 0.48 in boys; 0.51 in girls	SBPHR: Sensitivity 83% in boys; 94% in girls. Specificity 97% in boys; 92% in girls. DBPHR: Sensitivity 91% in boys; 99% girls. Specificity 100% in boys; 100% in girls

C. Ejike & al. Journal of Tropical Pediatrics. 2012 (12)	Not reported	716	Data from healthy school children in Umuahia, Abia State, Nigeria	7–10	Oscillometric method. 3 consecutive BP measures at one visit. Mean BP: average of the last 2 measures	SBPHR: 0.83-0.89 in boys; 0.81-0.88 in girls DBPHR:0.54-0.60 in boys; 0.54-0.59 in girls	SBPHR: Sensitivity 100% in boys; 100% in girls. Specificity 84.3-97.3% in boys; 80.3-100% in girls. DBPHR: Sensitivity 100% in boys; 100% in girls. Specificity 97.3-100% in boys; 92.5-100% in girls
O. Galescu & al. International Journal of Pediatrics. 2012 (13)	2006-2007	3775	National Health and Nutrition Examination Survey, USA	9.9-15.1	Auscultatory method. 3 consecutive BP measures at 1 visit. Mean BP: average of the last 2 measures	SBPHR: 0.75 in boys; 0.75 in girls DBPHR: 0.46 in boys ; 0.48 in girls	SBPHR: Sensitivity 95 % in boys; 97.2 % in girls. Specificity 83% in boys; 83.3% in girls. DBPHR: Sensitivity 92% in boys; 100% girls. Specificity 91.5% in boys; 95.5% in girls
Q. Lu & al. European Journal of Pediatrics. 2013 (14)	2011	1352	Population-based study of healthy Han children, China	7–12	Auscultatory method. 3 consecutive measures at 1 visit. Mean BP: average of the 3 measures. Children in the hypertensive range: repeated measures on 2 subsequent visits	SBPHR: 0.76–0.88 in boys; 0.78–0.90 in girls DBPHR:0.51–0.60 in boys; 0.51–0.58 in girls	SBPHR: Sensitivity 93.8–100% in boys; 92.9–100 % in girls. Specificity 80.0–93.7% in boys; 88.8–95.9% in girls DBPHR: Sensitivity 100% in boys; 100% girls. Specificity 92.5–100% in boys; 88.9–93.3 % in girls

Table 2: Characteristics of participants (N=5207; 2621 boys and 2586 girls). BP: blood pressure; SD: standard deviation; BPHR: blood-pressure-to-height-ratio.

Characteristics	Mean or N (proportion)	SD	Min	Max
Age [year]	12.3	0.5	10.1	14.9
Weight [kg]	44.3	9.4	18.2	18.2
Height [cm]	153.5	7.6	127.0	183.2
Systolic BP [mmHg]	112.9	9.9	72	161
Diastolic BP [mmHg]	65.8	7.1	37	102
Systolic BPHR [mmHg/cm]	0.74	0.06	0.50	1.02
Diastolic BPHR [mmHg/cm]	0.43	0.05	0.25	0.70
Body weight category				
Normal weight	4492 (86.3%)			
Overweight	625 (12.0%)			
Obesity	90 (1.7%)			
Elevated systolic BP[a]	569 (10.9%)			
Elevated diastolic BP[a]	96 (1.8%)			
Elevated systolic or diastolic BP[a]	595 (11.4%)			
Systolic hypertension[b]	110 (2.1%)			
Diastolic hypertension[b]	22 (0.4%)			
Systolic/diastolic hypertension[b]	113 (2.2%)			

a: elevated BP at the first screening visit; b: hypertension : elevated BP at three successive visits.

Table 3: Sensitivity, specificity, positive (PPV), and negative predictive (NPV) values of the systolic blood-pressure-to-height-ratio (BPHR) thresholds to identify children with A) systolic/diastolic hypertension and B) systolic hypertension.

	A) Systolic/diastolic hypertension						B) Systolic hypertension					
		No	Yes	Total	Sensitivity	100%		No	Yes	Total	Sensitivity	100%
Systolic BPHR ≥ 0.70	No	1541	0	1541	Specificity	30%	No	1541	0	1541	Specificity	30%
	Yes	3553	113	3666	PPV	3%	Yes	3556	110	3666	PPV	3%
	Total	5094	113	5207	NPV	100%	Total	5097	110	5207	NPV	100%
		No	Yes	Total	Sensitivity	100%		No	Yes	Total	Sensitivity	100%
Systolic BPHR ≥ 0.75	No	3164	0	3164	Specificity	62%	No	3164	0	3164	Specificity	62%
	Yes	1930	113	2043	PPV	6%	Yes	1933	110	2043	PPV	5%
	Total	5094	113	5207	NPV	100%	Total	5097	110	5207	NPV	100%
		No	Yes	Total	Sensitivity	92%		No	Yes	Total	Sensitivity	92%
Systolic BPHR ≥ 0.80	No	4352	9	4361	Specificity	85%	No	4352	9	4361	Specificity	85%
	Yes	742	104	846	PPV	12%	Yes	745	101	846	PPV	12%
	Total	5094	113	5207	NPV	100%	Total	5097	110	5207	NPV	100%
		No	Yes	Total	Sensitivity	55%		No	Yes	Total	Sensitivity	55%
Systolic BPHR ≥ 0.85	No	4905	51	4956	Specificity	96%	No	4906	50	4956	Specificity	96%
	Yes	189	62	251	PPV	25%	Yes	191	60	251	PPV	24%
	Total	5094	113	5207	NPV	99%	Total	5097	110	5207	NPV	99%
		No	Yes	Total	Sensitivity	28%		No	Yes	Total	Sensitivity	28%
Systolic BPHR ≥ 0.90	No	5060	81	5141	Specificity	99%	No	5062	79	5141	Specificity	99%
	Yes	34	32	66	PPV	48%	Yes	35	31	66	PPV	47%
	Total	5094	113	5207	NPV	98%	Total	5097	110	5207	NPV	98%

Table 4: Sensitivity, specificity, positive (PPV), and negative predictive (NPV) values of the diastolic blood-pressure-to-height-ratio (BPHR) thresholds to identify children with A) systolic/diastolic hypertension and B) diastolic hypertension.

	A) Systolic/diastolic hypertension						B) Diastolic hypertension					
		No	Yes	Total	Sensitivity	99%		No	Yes	Total	Sensitivity	100%
Diastolic BPHR ≥ 0.40	No	1414	1	1415	Specificity	28%	No	1415	0	1415	Specificity	27%
	Yes	3680	112	3792	PPV	3%	Yes	3770	22	3792	PPV	1%
	Total	5094	113	5207	NPV	100%	Total	5185	22	5207	NPV	100%
		No	Yes	Total	Sensitivity	79%		No	Yes	Total	Sensitivity	95%
Diastolic BPHR ≥ 0.45	No	3545	24	3569	Specificity	70%	No	3568	1	3569	Specificity	69%
	Yes	1549	89	1638	PPV	5%	Yes	1617	21	1638	PPV	1%
	Total	5094	113	5207	NPV	99%	Total	5185	22	5207	NPV	100%
		No	Yes	Total	Sensitivity	42%		No	Yes	Total	Sensitivity	68%
Diastolic BPHR ≥ 0.50	No	4746	65	4811	Specificity	93%	No	4804	7	4811	Specificity	93%
	Yes	348	48	396	PPV	12%	Yes	381	15	396	PPV	4%
	Total	5094	113	5207	NPV	99%	Total	5185	22	5207	NPV	100%
		No	Yes	Total	Sensitivity	12%		No	Yes	Total	Sensitivity	36%
Diastolic BPHR ≥ 0.55	No	5051	100	5151	Specificity	99%	No	5137	14	5151	Specificity	99%
	Yes	43	13	56	PPV	23%	Yes	48	8	56	PPV	14%
	Total	5094	113	5207	NPV	98%	Total	5185	22	5207	NPV	100%
		No	Yes	Total	Sensitivity	2%		No	Yes	Total	Sensitivity	9%
Diastolic BPHR ≥ 0.60	No	5089	111	5200	Specificity	100%	No	5180	20	5200	Specificity	100%
	Yes	5	2	7	PPV	29%	Yes	5	2	7	PPV	29%
	Total	5094	113	5207	NPV	98%	Total	5185	22	5207	NPV	100%

Table 5: Area under the receiver operating characteristic curve (AUC) for various thresholds of systolic and diastolic blood pressure to height ratio (BPHR) to discriminate children with or without systolic/diastolic hypertension, systolic hypertension, or diastolic hypertension, respectively.

	Systolic/diastolic hypertension AUC	Systolic hypertension AUC	Diastolic hypertension AUC
Systolic BPHR ≥ 0.70	0.65	0.65	-
Systolic BPHR ≥ 0.75	0.81	0.81	-
Systolic BPHR ≥ 0.80	0.89	0.89	-
Systolic BPHR ≥ 0.85	0.76	0.75	-
Systolic BPHR ≥ 0.90	0.64	0.64	-
Diastolic BPHR ≥ 0.40	0.63	-	0.64
Diastolic BPHR ≥ 0.45	0.74	-	0.82
Diastolic BPHR ≥ 0.50	0.68	-	0.80
Diastolic BPHR ≥ 0.55	0.55	-	0.68
Diastolic BPHR ≥ 0.60	0.51	-	0.55

Figure 1: Receiver operator curves (ROC) for A) systolic blood-pressure-to-height-ratio (BPHR) and B) diastolic BPHR.

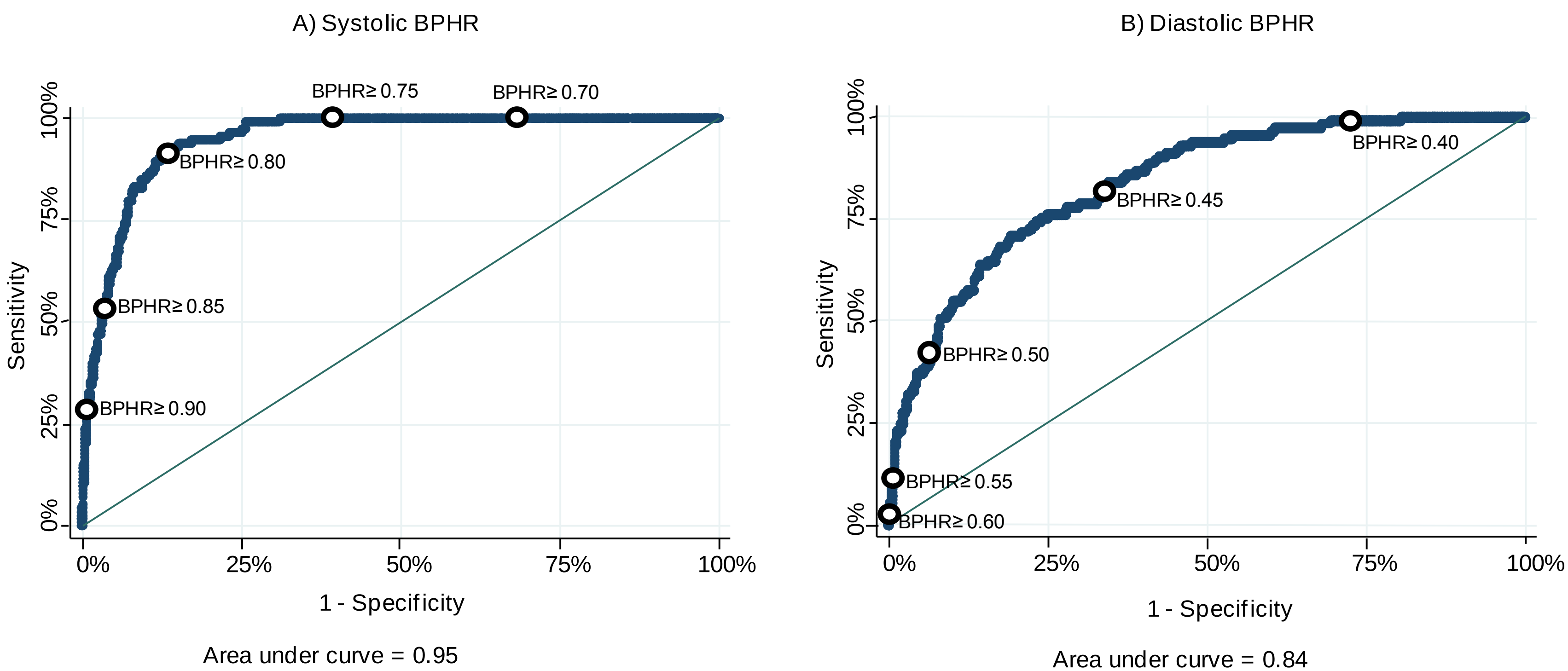

Figure 2: Use of systolic blood-pressure-to-height-ratio (BPHR) in the process of hypertension identification in children. The schema is also applicable for diastolic BPHR, with a cut-off set at 0.45 [mmHg/cm].