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CORRESPONDENCE

A new modified blood pressure-to-height ratio also simplifies the identification of high blood pressure in American children

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We read with great interest the paper by Ma *et al.*[1] that was published in *Hypertension Research* in December 2016. The authors reported that a new modified blood pressure (BP)-to-height ratio formula (MBPHR3 = BP/(height (cm)+3 × (13 − age in years))) was an accurate index for the screening of hypertension in Han children aged 7–12 years.

Systemic arterial hypertension is often underdiagnosed among children and adolescents.[2] Many factors contribute to that, but the intricate diagnostic process is the major one.[2] Unlike adults, healthy BP levels in children and adolescents vary with gender, age and height.[3] This generates the need to analyze multiple percentile tables to establish a correct diagnosis, a process that hardly applies to busy pediatric clinical scenarios.

In 2011, Lu *et al.*[4] described the BP-to-height ratio (BPHT) as a good screening method to identify hypertension in Chinese adolescents. However, despite the method's great efficacy in adolescents, it showed less encouraging results in children.[5] To overcome this problem, we proposed a modified BP-to-height ratio formula (MBPHR7 = BP/(height (cm)+7 × (13 − age in years).[6] The rationale for this formula was that the great difference in height and BP among children under 13 years negatively influence the accuracy of the BPHT screening method, and that the use of MBPHR7 could partially nullify such influence. This hypothesis was tested in Brazilian children, and MBPHR7 showed better results than BPHT. Interestingly, the new formula reported by Ma *et al.*[1] (MBPHR3), which was based on our previously published MBPHR7,[6] but used the factor 3 instead of 7, was associated with a greater accuracy in identifying hypertension in Chinese children as compared with the BPHT and MBPHR7 formulae. However, as also stated by the authors, confirmation of this finding in other populations is required.

To verify the MBPHR3 efficacy among American children, we used data from the National Health and Nutrition Examination Survey (NHANES) 1999–2014. The details of this survey have been described elsewhere.[7] Briefly, the National of Health Statistics of the Centers for Disease Control and Prevention (CDC) conducts this survey since 1999 in a non-institutionalized American population. Written confirmed consent and assent were obtained from parents and their children. Only patients with systolic BP (SBP) and diastolic BP (DBP) measurements and the complete data for height, weight, gender and age between 8 and 12 years were included in the present analysis (only children older than 8 years had measured BP values). A total of 6587 cases were analyzed.

The MBPHR7 formula was: SBP or DBP (mm Hg)/(Height(cm)+7 × (13 − age(in years)). The MBPHR3 formula was: SBP or DBP (mm Hg)/(Height(cm)+3 × (13 − age(in years)). BPHT was estimated as SBP or DBP (mm Hg)/Height (cm). Receiver Operator Characteristics curves (ROC) were plotted to identify optimal thresholds for each method with the Younden's index (sensitivity +specificity-1). Body mass index (BMI) was calculated as weight (kg)/height^2(m^2) and classified as underweight, normal, overweight or obese in accordance with the tables presented by the CDC. The gold standard for the diagnosis of hypertension and pre-hypertension was based on the definitions of The Fourth Report on diagnosis, evaluation, and treatment of high BP in children and adolescents,[3] which construct nomograms specifically to American population and have better statistical quality.[8] Such guideline uses gender, age and height to determinate the normal values of BP in children and adolescents. Therefore, hypertension was defined as SBP or DBP ⩾ 95th percentile and pre-hypertension as SBP or DBP ⩾ 90th percentile and <95th percentile. Afterwards, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of each method were calculated with the respective confidence intervals. The software used was MedCalc 16.8.4 (Software bvba, Ostend, Belgium).

A total of 3269 boys with mean ± s.d. SBP of 103.5 ± 9.7 mm Hg; DBP of 54.5 ± 12.0 mm Hg; height 144.2 ± 11.3 cm; BMI of 19.9 ± 4.7 kg m^{-2} and 3318 girls with SBP of 102.7 ± 10.0 mm Hg; DBP 55.6 ± 11.1; height of 145.0 ± 11.5 cm; BMI 20.4 ± 5.0 kg m^{-2} were included in the present study. Additionally, 3.92% of the participants were pre-hypertensive and 2.84% hypertensive. Regarding BMI, 18.02% were on overweight and 24.96% were obese.

The supplementary file demonstrates the ROC curves used to identify pre-hypertension and hypertension based on SBP and DBP values according to the studied methods (MBPHR3, MBPHR7 and BPHT). Table 1 shows the yielded cutoff points for each method and their respective values of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) with confidence intervals. MBPHR3 showed higher specificity and PPV than MBPHR7 and BPHT, with similar sensitivity in most cases. Thus, the current analysis reinforces the possibility of using MBPHR3 as a screening method for high BP in children.

Table 1 Cutoff points, pre-tests and post-tests of BPHT, MPBHR3 and MPBHR7

	Cutoff points (SBP/DBP)	*Sensitivity (CI), %*	*Specificity (CI), %*	*PPV (CI), %*	*NPV (CI), %*
BPHT					
BP⩾90th					
Male	0.79/0.50	92.7 (88.4–95.8)	84.8 (83.5–86.1)	30.3 (26.9–34.0)	99.4 (99.0–99.6)
Female	0.77/0.50	96.0 (92.6–98.2)	82.3 (80.9–83.6)	28.5 (25.3–31.8)	99.6 (99.3–99.8)
BP⩾95th					
Male	0.81/0.51	98.8 (93.2–100)	87.4 (86.2–88.6)	16.5 (13.3–20.1)	100 (99.8–100)
Female	0.80/0.52	95.3 (89.4–98.5)	88.8 (87.7–89.9)	22.1 (18.4–26.2)	99.8 (99.6–99.9)
MPBHR3					
BP⩾90th					
Male	0.76/0.48	93.1 (88.9–96.1)	92.7 (91.7–93.6)	47.5 (42.7–52.4)	99.5 (99.1–99.7)
Female	0.74/0.48	96.0 (92.6–98.2)	89.8 (88.7–90.9)	40.9 (36.8–45.3)	99.7 (99.4–99.8)
BP⩾95th					
Male	0.78/0.49	97.5 (91.3–99.7)	94.0 (93.1–94.8)	29.0 (23.6–34.8)	99.9 (99.8–100)
Female	0.77/0.50	97.2 (92.0–99.4)	95.4 (94.6–96.1)	41.3 (35.1–47.6)	99.9 (99.7–100)
MPBHR7					
BP⩾90th					
Male	0.69/0.44	96.8 (93.5–98.7)	86.2 (85.0–87.4)	33.4 (29.8–37.3)	99.7 (99.4–99.9)
Female	0.69/0.45	95.1 (91.5–97.6)	90.3 (89.2–91.3)	41.9 (37.6–46.3)	99.6 (99.3–99.8)
BP⩾95th					
Male	0.71/0.47	97.5 (91.3–99.7)	90.8 (89.8–91.8)	21.1 (17.0–25.6)	99.9 (99.7–100)
Female	0.70/0.45	96.3 (90.7–99.0)	89.9 (88.9–91.0)	24.2 (20.2–28.5)	99.9 (99.6–100)

Abbreviations: BP, blood pressure; BPHT, BP-to-height ratio; CI, confidence interval; DBP, diastolic BP; MBPHR3, modified BP-to-height ratio (with factor 3); MBPHR7, modified BP-to-height ratio (with factor 7); NPV, negative predictive value; PPV, positive predictive value; SBP, systolic BP.

Regarding the equation elaboration, the MBPHR7 uses factor 7 to describe the mean height variation per year between 5 and 13 years (~7 cm per year). Ma *et al.*[1] identified that factor 3 is superior for diagnostic purposes, but only a minority of children grow only 3 cm per year. At a first glance, this may seem as a counterpoint to the logic of MBPHR3. However, it has been demonstrated that the progressive increase of BP in children and adolescents is more correlated with the growth of the trunk instead of the whole body.[9] Coincidentally, the trunk grows approximately 3 to 4 cm per year in this age group.[10] Therefore, we believe that this new formula is more efficient because it probably considers the variation in the size of the trunk, instead of the whole body.

In conclusion, MBPHR3 showed better results than MBPHR7 and BPHT in identifying hypertension and pre-hypertension in American children aged 8–12 years with a low number of cutoff points. This fact may be related to the higher correlation between the variation of trunk size and BP. The use of this method may improve the diagnosis of high BP in children and thus prevent the progression of this condition.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Felipe Alves Mourato[1,2], Wilson Nadruz Junior[2,3] and Sandra da Silva Mattos[1,2]

[1]Círculo do Coração de Pernambuco-Recife, Pernambuco, Brazil; [2]Laboratório de Imunopatologia Keizo Asami (LIKA)-Recife, Pernambuco, Brazil and [3]Departamento de Clínica Médica—Universidade de Campinas, São Paulo, Brazil
E-mail: felipe.a.mourato@gmail.com

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Supplementary Information accompanies the paper on Hypertension Research website (http://www.nature.com/hr)