Paediatrica Indonesiana

VOLUME 49 July • 2009 NUMBER 4

Original Article

Number of blood pressure measurements needed for screening of hypertension in children and adolescents

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Abstract

Background Routine blood pressure assessment is recommended because childhood hypertension is significantly associated with increased risk of cardiovascular disease in adulthood. However, results of blood pressure measurements in children are highly variable, associated with the risk of under or over-diagnosing in hypertension.

Objective To assess the optimal number of measurements to screen elevated blood pressures in children and adolescents.

Methods This study used two sets of data, i.e. a dataset from 104 obese and non-obese, male and female primary school-children, and a dataset from 79 obese female adolescents. Blood pressure (BP) was measured using standard techniques described by the fourth report of the National High Blood Pressure Education Program (NHBPEP) Working Group on Children and Adolescents. Elevated BP was defined as systolic and diastolic BP at or above the 90th percentile for gender, age, and height.

Results BP measurements taken on day-one were significantly higher than those taken on day-two and three. This led to higher prevalence of elevated BP when only one measurement was performed. Using the average of two measurements in two occasions detected elevated blood pressure with specificity and positive predictive value (PPV) ranged from 0.74 to 1.0 and 0.58 to 1.0, respectively.

Conclusions It is necessary to measure blood pressure repeatedly to minimize the risk of over-diagnosing in hypertension in children and adolescents. Using the average of three measurements in three visits is recommended, but drawing conclusions based on two measurements in two occasions have yielded sufficiently high specificity. **[Paediatr Indones. 2009;49:229-33]**.

Keywords: blood pressure, hypertension, screening, child, adolescents

Cardiovascular disease is a major cause of morbidity and mortality in adults.[1] It has been widely recognized that the risk for developing the disease begins very early in life. Elevated blood pressure in childhood, along with obesity, insulin resistance and dyslipidemia, have been significantly associated with higher risk for hypertension, coronary artery atherosclerosis, and left ventricular hypertrophy later in life.[2-4] Recognizing these substantial long-term health risks for hypertensive children and adolescents, the National High Blood Pressure Education Program (NHBPEP) Working Group on Children and Adolescents of the American Association of Pediatrician (AAP) in their fourth report recommends routine measurement of blood pressures in children >3 years old.[5] However, as it has also been widely known that results of blood pressure measurements in children can be highly variable, the working group demands repeated measurements before hypertension in children can be diagnosed.[5]

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Sorof *et al*,[6] in 2004, reported that the prevalence of elevated blood pressure decreased from 19.4% in the first screening, to 9.5% in the second screening and 4.5% in the third screening. Similarly, Gillman *et al*[7,8] reported a higher tracking after measurements on multiple visits, i.e. 4 visits. The working group recommended using the average of three visits.[5)] However, Chen *et al*[3], in 2007, observed that measurements of ≥3 times did not improve the tracking of blood pressure compared to two measurements. In this paper, we used two data sets of blood pressure measurements to assess the optimal number of measurements to screen for elevated blood pressures in children and adolescents.

Methods

This paper used two sets of data, i.e. a dataset from 104 obese and non-obese, male and female primary school-children and a dataset from 79 obese female adolescents. The first dataset was collected in 2006 with the primary objective of comparing blood pressures of obese and non-obese, male and female primary school-children. The second dataset was collected in 2007 with the primary objective of assessing the association between blood pressure and insulin resistance in obese female adolescents.

Blood pressure (BP) was measured using the standard techniques described by the fourth report of the NHBPEP Working Group on Children and Adolescents.[5] All measurements were performed in the morning, on three different occasions or days. These measurements would be mentioned as measurements on day-one, day-two and day-three, respectively.

In the dataset of primary school-children, only one measurement per day was performed. In the dataset of obese female adolescents, the measurements were performed in triplicate, around 5 minutes apart.

The BP was measured in the classroom by trained medical students using a standard clinical mercury sphygmomanometer and a stethoscope (Riester®). The stethoscope was placed over the brachial artery pulse, proximal and medial to the cubital fossa. Appropriate size cuffs for the children's or the adolescents' right arms were used. The appropriateness of the cuff's sizes was checked by measuring the subjects' right upper arm circumference. Right mid-upper-arm circumference was measured at a point midway between the olecranon and the acromion, using a non-stretchable measurement tape, to the nearest 0.1 cm.

After at least 10 minutes rest from recent activity, the children or the adolescents were asked to sit in a comfortable sitting position with their right arm fully exposed and resting on a supportive surface at the heart level. Blood pressures were measured on the right arm, using appropriate cuff size. When more than one measurement was taken, a 5 minutes-rest were given before the subsequent measurement was performed.

The cuff was rapidly inflated to about 20 mm Hg above the point at which the radial pulse disappeared. The pressure within the cuff was then released at a rate about 2 to 3 mm Hg per second while auscultation was performed over the brachial artery. The systolic BP was determined by the onset of the "tapping" Korotkoff sound. The diastolic BP was defined as the disappearance of the sound (the fifth Korotkoff sound). Both systolic and diastolic BP was recorded to the nearest 2 mmHg.

The percentiles of every subject's systolic and diastolic BP were computed using the formula given by the fourth report of the NHBPEP Working Group on Children and Adolescents.[5] Elevated BP was defined as systolic and diastolic BP at or above the 90th percentile for gender, age and height. While elevated BP was actually comprised of hypertension, i.e. BP at or above the 95th percentile, and pre-hypertension, i.e. BP less than the 95th percentile, we used only the definition of elevated BP to simplify analyses.[5]

Data of the children's and the adolescents' ages were obtained from the schools' files. Height was measured to the nearest 0.1 cm using a portable stadiometer with the subjects standing without shoes facing the examiner. For calculation of BP percentiles, data of heights were converted to *z*-scores based on the year 2000 sex specific Center for Disease Controls and Prevention (CDC) growth charts[9] using the nutritional anthropometry module (NutStat) of the CDC's Epi Info 2000 (Centers for Disease Control and Prevention, Atlanta, Georgia, USA).

Pearson correlations were used to assess the correlations between BP measurements. Paired t-tests were used to assess the differences between measurements. Sensitivity, specificity, positive and negative predictive value of the measurements on day-one only or the average of day-one and day-two were compared to the standard requirements, i.e. the average of the three measurements. Estimates and 95% confidence intervals were presented; statistical significance was set to $\alpha<0.05$. Statistical computation was performed with VassarStat: Website for Statistical Computation (available at http://faculty.vassar.edu/lowry/VassarStats.html).

Results

The first dataset consisted of 104 obese and non-obese, male and female children aged 10.6 (SD 0.7) years old, while the second dataset consisted of 79 obese female adolescents aged 13.7 (SD 0.9) years old. Blood pressure (BP) measurements taken on day-one, day-two, and day-three were significantly correlated with each other. However, in both datasets, measurements taken on day-one were significantly higher than those taken on day-two and three. BP measurements taken on day-two were slightly higher than those taken on day-three, but the differences were not statistically significant. Similar findings were observed for both systolic and diastolic BP (**Table 1**).

For dataset of obese female adolescents, in which the measurements of BP in every occasion were done in triplicate, there were no significant differences between the measurements performed in one occasion/ day (data not shown). The mean of the three measurements within one occasion/ day was used for further analyses.

The variability of BP measured in the three separate occasions had resulted in a variety of conclusions regarding the presence of elevated BP. The prevalence of elevated BP was higher in day-one, less in day-two and the least in day-three. In the dataset of obese female adolescents, 31 girls (39.2%) would be considered to have elevated systolic BP when only day-one measurements were taken, 24 (30.4%) when the average of measurements taken on day-one and day-two were considered and 15 (19.0%) when the average of the measurements taken on day-one, day-two and day-three were all considered. Only six girls

Table 1. Correlations and mean differences between measurements performed on different occasions/ days in both datasets

Measurements	Mean (SD) mmHg	Compared to	Correlationsa r	Correlationsa P	Mean difference (95%CI)	P
A. Dataset of primary school-children (n=104)						
Systolic BP						
day-one	101.1 (14.1)	vs. day-two	0.75	<0.001	2.58 (0.74; 4.41)	0.006
		vs. day-three	0.77	<0.001	2.90 (1.14; 4.66)	0.001
day-two	98.5 (12.2)	vs. day-three	0.87	<0.001	0.33 (-0.88; 1.54)	0.59
day-three	98.2 (12.0)					
Diastolic BP						
day-one	67.8 (11.4)	vs. day-two	0.68	<0.001	3.69 (1.97; 5.42)	<0.001
		vs. day-three	0.63	<0.001	3.87 (2.01; 5.72)	<0.001
day-two	64.1 (10.6)	vs. day-three	0.79	<0.001	0.17 (-1.20; 1.54)	0.80
day-three	63.9 (10.9)					
B. Dataset of obese female adolescents (n=79)						
Systolic BP						
mean of day-one	116.6 (10.7)	vs. mean of day-two	0.57	<0.001	2.66 (0.46; 4.87)	0.02
	-	vs. mean of day-three	0.51	<0.001	4.38 (2.21; 6.55)	<0.001
mean of day-two	114.0 (10.6)	vs. mean of day-three	0.45	<0.001	1.72 (-0.54; 3.98)	0.14
mean of day-three	112.3 (8.3)					
Diastolic BP						
mean of day-one	81.8 (8.4)	vs. mean of day-two	0.30	0.008	3.13 (1.00; 5.26)	0.005
	-	vs. mean of day-three	0.44	<0.001	4.73 (2.85; 6.61)	<0.001
mean of day-two	78.7 (7.6)	vs. mean of day-three	0.19	0.10	1.60 (-0.55; 3.75)	0.14
mean of day-three	77.1 (7.4)					

[a] Pearson correlations
[b] Paired sample t-tests

(7.6%) had consistently elevated systolic BP. Similar findings were observed for diastolic BP and for systolic and diastolic BP of the other dataset (**Table 2**).

Using the criteria set in the fourth report of the NHBPEP Working Group on Children and Adolescents[5], i.e. elevated BP should be determined from the average of BP measurements taken on at least 3 separate occasions, the prevalence (95%CI) of elevated blood pressure in obese female adolescents was 0.19 (0.11 to 0.30) for systolic and 0.61 (0.49 to 0.71) for diastolic BP. Meanwhile, the prevalence of elevated blood pressure in the dataset of primary school-children was 0.07 (0.03 to 0.14) for systolic and 0.13 (0.07 to 0.21) for diastolic BP. We calculated the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of BP measurements taken only on day-one or the average of day-one and day-two compared to the average of the three days' measurements (**Table 3**).

Discussion

These two sets of data showed that the variability of BP measured in three separate occasions had resulted in a variety of conclusions regarding the presence of elevated BP. For instance, in the dataset of obese female adolescents, the prevalence of elevated systolic BP ranged from 7.6%, when a strict requirement of consistently elevated was used, to 48.1%, when a looser requirement of at least one elevation was used. The strict requirement will result in more hypertensive children not considered hypertensive, while the looser one will cause over-diagnosis of hypertension, i.e. unnecessarily labeling hypertension to normal children. However, an error to the over-diagnosis side seems to be more probable because measurement on the first visit is usually the highest, resulting in more children labeled hypertensive. Sorof *et al*[6] had reported that the prevalence of elevated BP after first, second, and third screenings was 19.4%, 9.5% and 4.5%, respectively.

Similar to what was reported by Gillman and Cook[8], in 1995, both of our data sets showed that the measurements on the first day resulted in significantly higher results compared to the measurements on the subsequent occasions. The results of the measurements on day-two were still slightly higher than those on day-three but the differences were not statistically significant.

The fourth report of the NHBPEP Working Group on Children and Adolescents recommended the use of the average BP of at least 3 separate occasions for classifying blood pressures. Normal BP is defined as systolic and diastolic BP that is $<90^{th}$ percentile for gender, age and height. Hypertension is defined as the average of systolic and diastolic BP that is $\geq 95^{th}$ percentile, while BP $\leq 90^{th}$ percentile but less than the 95^{th} percentile is considered prehypertensive.[5]

Calculating sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) in defining elevated BP for measurements taken on day-one or the average of day-one and day-two compared to the average of the three days' measurements showed that adding the day-two measurement will significantly improve the specificity and the PPV of elevated BP. Because of the relatively higher readings on the first occasion, sensitivity and NPV was already sufficiently high with only one measurement.

This observation means that with only one measurement we are at risk of classifying hypertension in too many children, but the risk can be greatly minimized by considering the second measurements on the second visits. Chen *et al*[3] reported that BP tracking was higher with multiple measurements, but measurements $\geq$ 3 times did not improve the tracking further compared with two measurements.

Table 2. The prevalence of elevated blood pressure (BP)

Measurements on	Dataset of primary school-children (n=104)		Dataset of obese female adolescents (n=79)	
	systolic BP (%)	diastolic BP (%)	systolic BP (%)	diastolic BP (%)
day-one	18 (17.3)	28 (26.9)	31 (39.2)	56 (70.9)
day-two	6 (5.8)	10 (9.6)	18 (22.8)	44 (55.7)
day-three	2 (1.9)	13 (12.5)	13 (16.5)	36 (45.6)
average of day-one and day-two	7 (6.7)	14 (13.5)	24 (30.4)	54 (68.4)
average of the three days' measurements	5 (4.8)	13 (12.5)	15 (19.0)	48 (60.8)
consistently elevated	1 (1.0)	3 (2.9)	6 (7.6)	20 (25.3)
at least one elevated measurement	20 (19.2)	35 (33.7)	38 (48.1)	68 (86.1)

Table 3. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) in defining elevated blood pressure

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
A. Dataset of primary school-children (n=104)				
Systolic BP				
day-one	1.00 (0.56-1.00)	0.89 (0.80-0.94)	0.39 (0.18-0.64)	1.00 (0.95-1.00)
average of day-one and day-two	0.71 (0.30-0.95)	1.00 (0.95-1.00)	1.00 (0.46-1.00)	0.98 (0.92-1.00)
Diastolic BP				
day-one	0.77 (0.46-0.94)	0.80 (0.70-0.88)	0.36 (0.19-0.56)	0.96 (0.88-0.99)
average of day-one and day-two	0.77 (0.46-0.94)	0.96 (0.86-0.99)	0.71 (0.42-0.90)	0.97 (0.90-0.99)
B. Dataset of obese female adolescents (n=79)				
Systolic BP				
day-one	0.87 (0.58-0.98)	0.72 (0.59-0.82)	0.42 (0.25-0.61)	0.96 (0.85-0.99)
average of day-one and day-two	0.93 (0.66-1.00)	0.84 (0.73-0.92)*	0.58 (0.37-0.77)	0.98 (0.89-1.00)
Diastolic BP				
day-one	0.85 (0.72-0.93)	0.52 (0.33-0.69)	0.73 (0.59-0.84)	0.70 (0.47-0.86)
average of day-one and day-two	0.96 (0.85-0.99)	0.74 (0.55-0.87)*	0.85 (0.72-0.93)	0.92 (0.72-0.99)

*Significantly higher than when only measurement on day-one was used (p<0.05)

We concluded that it is necessary to measure blood pressure repeatedly to minimize the risk of over-diagnosing hypertension in children and adolescents. Using the average of three measurements in three visits as recommended by the fourth report of the NHBPEP Working Group on Children and Adolescents would be the best, but drawing conclusions based on two measurements in two occasions seem to have yielded sufficiently high specificity.

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