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ORIGINAL ARTICLE

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Blood pressure nomograms for school children in Iran

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Abstract Currently there are no blood pressure (BP) nomograms based on local data available in Iran. In order to obtain data on BP distribution in Iranian school children, 8,848 children aged 7–12 years were studied in Tehran. BP was found to increase with age. Both systolic and diastolic BP showed a positive correlation with height and weight in both sexes. The systolic and diastolic BP in boys and girls were not significantly different. As the sample was representative of Iranian school children, reference standard curves were constructed by modeling data using fractional polynomial. The 50th and 95th percentiles of systolic and diastolic BP of Iranian children were compared for each age with the results reported in the study of the Second Task Force. These percentiles were different from the Second Task Force study. Environmental and genetic determinants are likely to be responsible for the differences. The differences show that the use of local BP nomograms is necessary for assessing the BP levels in Iranian children.

Keywords Blood pressure · Iranian school children · Nomograms

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Introduction

Hypertension in the adult population is associated with an increased incidence of stroke, coronary heart disease, congestive heart failure, and renal insufficiency [1]. Because the origin of some cases of adult hypertension may lie in childhood or adolescence, preventive intervention begun early in life may reduce the risks of cardiovascular disease and target organ damage during later life. Therefore, screening of blood pressure (BP) in children is important for the early detection and prevention of adult cardiovascular sequelae [2, 3, 4]. BP measurements should be interpreted according to the normal childhood BP distribution. The Second Task Force and new normative BP reports related to age, height, and weight from birth to 18 years are currently considered the primary reference standards for children and adolescents [2, 5]. However, the distribution of BP level and the prevalence of hypertension vary in different racial and ethnic groups [6, 7, 8].

There are no BP nomograms based on local data available in Iran. The purpose of the present study was to provide age-related reference standards for Iranian children based on representative data. We also compared our reference values with those reported by the Second Task Force [5].

Materials and methods

Data

The study included 8,848 school children (grade 1 through 5) aged 7–12 years who were studied between November 2000 and November 2002 in 20 different schools in Tehran as representative of school children in Iran, as advocated by Hosseini et al. ([9]; Hosseini et al. unpublished data). Tehran is divided into 20 regions for administrative purposes. In each part of the city, one boys' school and one girls' school was selected randomly from the list of schools. All healthy children were studied in each selected school.

The criteria for "healthy children" were: (1) being well or apparently normal; (2) absence of fever or documented underlying disease; (3) no evidence of hemodynamically significant illness such as congenital heart disease, or prior cardiac catheterization, or thoracic surgery; (4) no antihypertensive medication at the time of study. Two subjects with renal scarring on the technetium-99m dimercaptosuccinic acid scan (reflux nephropathy) and 1 with coarctation of the aorta, who had significant hypertension according to criteria of the Second Task Force [5], were excluded from the study.

Data were collected by trained medical staff. Informed consent was obtained from parents or guardians and the procedure was explained to the child before measuring his/her BP. Standard mercury sphygmomanometers (Model 1002/ Presameter, Riester, Germany) were used for all recordings. Ages were recorded in complete years. Height (cm) without shoes was measured using a stadiometer (Seca Model 207 Germany) with the student standing erect with the heels and back against a vertical scale. Weight without shoes and heavy outer clothing was measured on a balanced scale (Seca Model 710 Germany) that was calibrated daily.

The BP measurements were taken during the regular school day by five trained observers, with the child in a comfortable sitting position and after at least a 5-min rest. The right arm was positioned at heart level.

A cuff was selected with a bladder width approximately 40% of the arm circumference and long enough to cover 80%–100% of the arm circumference. The cuff was placed on the arm leaving the antecubital fossa free for auscultation, and inflated to a level that occluded the pulse at the wrist. The stethoscope was placed over the brachial artery and the cuff was deflated. First Korotkoff (K1) phase was used as a measure for systolic BP and fourth Korotkoff (K4) phase was used as a measure for diastolic BP. The mean of two readings with an interval of at least 30 s at each examination was used for data analysis.

Statistical analysis

Reference standard curves were constructed by modeling data in Stata 7.0 [10] using fractional polynomial [11]. To derive the reference standard curves (smoothed percentiles), first the BP measurements were transformed to the logarithmic scale in order to obtain approximate normal distributions. Then the variations in mean and standard deviations of the BP measurements across ages were modeled with age using fractional polynomials in Stata 7.0. The nomograms presented were derived by back transformation.

Linear regression analysis was used to estimate the average annual increase of systolic and diastolic BP. Pearson coefficient of correlation was also computed between systolic and diastolic BP and height and weight measurements.

Results

Systolic and diastolic BP measurements of 4,372 (49.4%) boys and 4,476 (50.6%) girls (aged 7–12 years living in Tehran), together with their height (cm) and weight (kg), were used for this analysis. The age/sex distribution of BP, weight, and height measurements of the children are given in Table 1.

Separate BP nomograms (50th, 75th, 90th, and 95th percentile curves) were constructed for systolic and diastolic BP measurements for boys and girls and shown to fit the data well. The BP nomograms are shown in Fig. 1. Smooth percentile values according to age and sex are given in Table 1.

As shown in Fig. 1, the shapes of the systolic and diastolic BP curves are similar for boys and girls. Systolic and diastolic BP percentiles increase gradually with age in both sexes.

Table 1 shows that all 50th, 75th, 90th, and 95th systolic BP percentiles were very close for boys and girls up to 9 years old. The corresponding percentiles were higher for girls than boys for ages 10, 11, and 12 years. However, diastolic BP percentiles were higher in boys than girls. The differences between sexes in the 90th and 95th percentiles become very small as the age increases.

The average annual increase in systolic BP was 2.05 mmHg in boys and 2.35 mmHg in girls. The average annual increases in diastolic BP from 7 through 12 years for boys and girls were 2.18 mmHg and 1.98 mmHg, respectively.

There was a strong positive correlation of systolic and diastolic BP with height and weight in both sexes. In boys, the coefficients of correlation of systolic and diastolic BP with height were 0.40 ($P<0.0001$) and 0.33 ($P<0.0001$), and with weight 0.41 ($P<0.0001$) and 0.37 ($P<0.0001$), respectively. In girls, the coefficients of correlation of systolic and diastolic BP with height were 0.43 ($P<0.0001$) and 0.32 ($P<0.0001$), and with weight 0.44 ($P<0.0001$) and 0.36 ($P<0.0001$), respectively.

Table 1 Smoothed percentile of blood pressure (BP) and mean (SD) of weight and height measurements by sex and age

Age (years) and sex	*n*	Smoothed percentile systolic BP (mm/Hg)				Smoothed percentile diastolic BP (mm/Hg)				Weight (kg) Mean (SD)	Height (cm) Mean (SD)
		50th	75th	90th	95th	50th	75th	90th	95th		
Boys											
7	493	101.6	106.0	109.9	112.2	59.3	64.4	68.4	70.7	21.0 (3.7)	118 (6)
8	701	103.9	108.7	112.9	115.4	61.7	66.7	70.6	72.8	23.9 (4.9)	125 (6)
9	764	106.2	111.4	115.9	118.6	63.8	68.6	72.4	74.5	27.5 (5.6)	131 (6)
10	990	108.4	113.9	118.7	121.6	65.6	70.3	74.0	76.0	30.3 (6.6)	135 (7)
11	1096	110.2	116.0	121.1	124.1	67.2	71.8	75.3	77.3	33.8 (7.4)	140 (7)
12	327	111.4	117.5	122.9	126.0	68.7	73.0	76.5	78.3	36.5 (9.1)	143 (6)
Girls											
7	489	101.5	106.0	110.0	112.4	58.2	63.4	67.5	69.8	20.8 (4.2)	118 (6)
8	700	103.9	108.8	113.2	115.8	61.4	66.6	70.7	73.0	22.8 (4.8)	123 (6)
9	835	106.4	111.7	116.5	119.3	63.7	68.8	72.9	75.2	25.5 (5.6)	128 (6)
10	985	108.8	114.4	119.5	122.5	65.4	70.4	74.4	76.7	29.8 (6.9)	135 (7)
11	1120	110.8	116.8	122.1	125.3	66.7	71.6	75.5	77.7	33.7 (8.0)	141 (8)
12	347	112.2	118.4	124.0	127.4	67.7	72.5	76.3	78.4	36.6 (9.4)	145 (8)

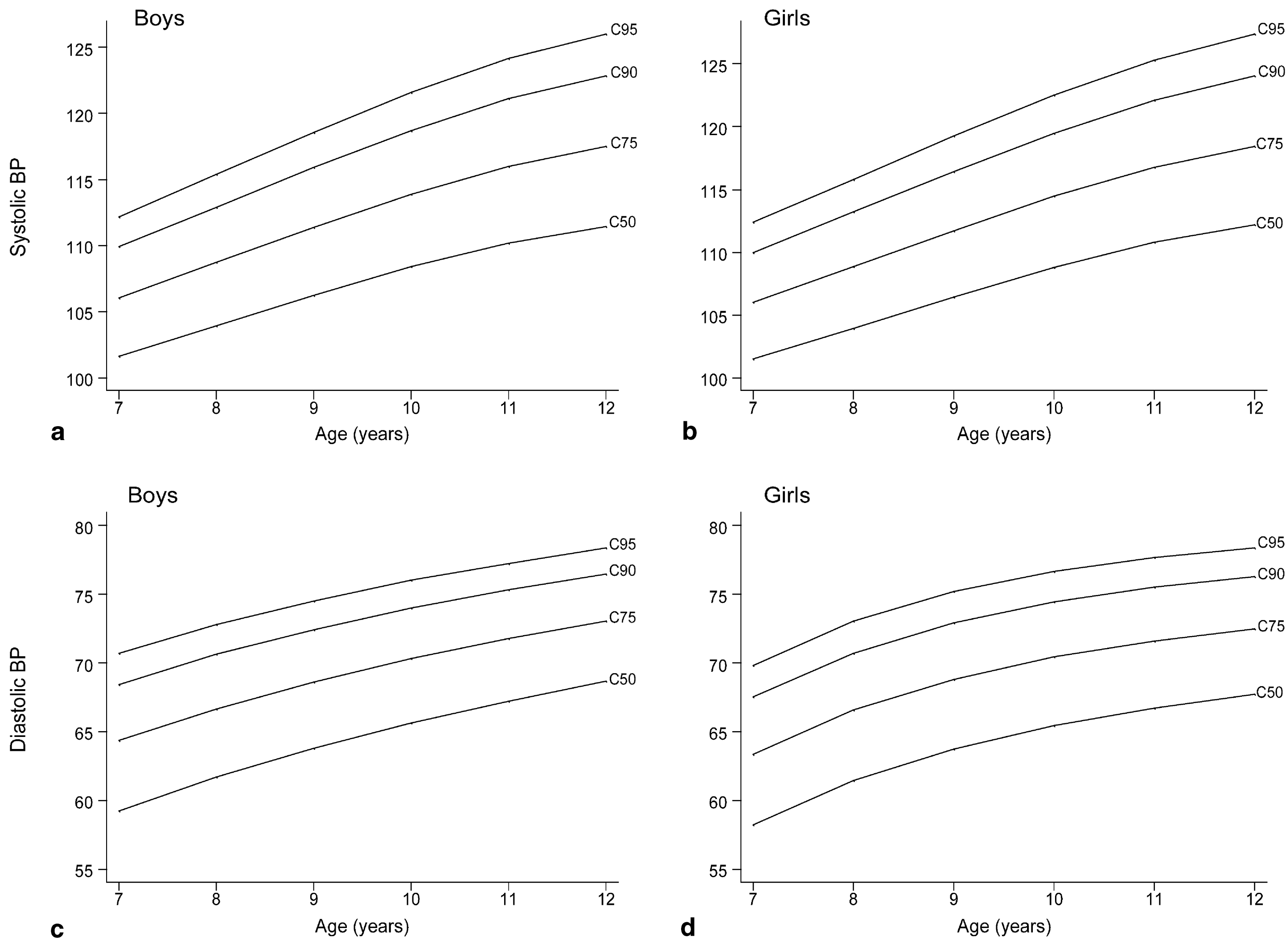

Fig. 1a–d The systolic and diastolic blood pressure (BP) nomograms for Iranian boys and girls (7–12 years). Percentiles are 50th, 75th, 90th, and 95th

Discussion

Hypertension in adults is a major cause of cardiovascular morbidity and mortality [12, 13]. Tracking of BP suggests that essential hypertension in adults is the result of a process that begins in childhood [1, 3]. Therefore, monitoring BP of children and adolescents is important for the early detection and prevention of adult hypertensive disease. BP values should be compared with normal curves before deciding on their normality. However, the distribution of BP values varies in different ethnic groups [14, 15, 16].

BP measurements were found to increase with age in both sexes in our study. This has been reported in all populations studied [1, 2, 3, 4, 5, 6, 7, 8]. The rise was steeper from 7 to 9 years than the rise from 10 to 12 years. For practical monitoring purposes, the systolic and diastolic BP percentile values were not significantly different across ages in boys and girls, as observed in other studies [6, 17].

The average annual increase in systolic and diastolic BP measurements of Iranian school boys and girls (2.05 mmHg, 2.18 mmHg, and 2.35 mmHg,1.98 mmHg, respectively) were higher than observed by Tümer et al. [6] and Sharma et al. [17] in their recent studies of Turkish and Indian children. This is because the 50th or 95th percentiles of systolic BP of Iranian children are initially lower than their Turkish counterparts. Similarly, the differences in the diastolic BP percentiles are fewer at 11 and 12 years; however, they are more at 7 years for Turkish boys and girls [6].

Several authors have reported strong positive correlations between BP measurements and height, weight, and body mass indices [6, 17, 18, 19, 20]. In our study positive correlations were also found between systolic and diastolic BP and height and weight in both sexes. However, the coefficients of correlation in our study were somewhat lower than those reported by Tümer et al. [6].

In this study we present data on BP measurements of children living in Tehran that may be used as representative of Iranian school children, as shown by Hosseini et al. ([9]; unpublished data). Hosseini et al. in their unpublished study of hypertension of 6,856 Iranian

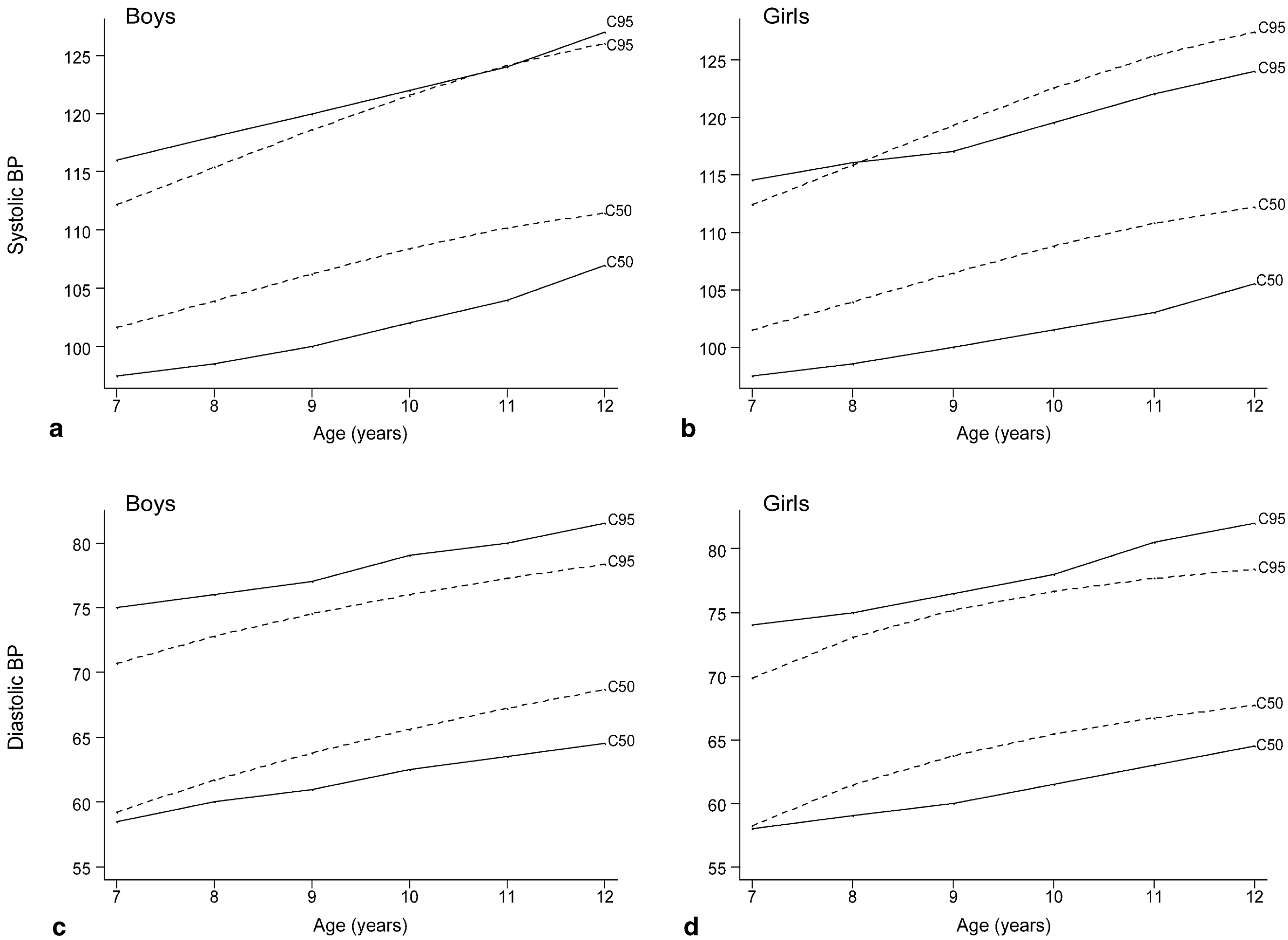

Fig. 2a–d Comparison of systolic and diastolic BP, Second Task Force (*unbroken line*) and Iranian standards (*dotted line*) for boys and girls. Percentiles are 50th and 95th

adolescents aged 12–18 years (based on data collected in the Iranian National Health Survey 1990–1992) showed that the 50th percentile of BP measurements of adolescents in Tehran is not significantly different from their rural counterparts or from their urban counterparts from the other provinces (P>0.2). They also found that the corresponding higher percentiles (90th, 95th) of BP measurements were not significantly different. These results are also thought to be similar for school children. In general, these findings are in accordance with observations of Preece (personal communication 1994) that, in the developing world, capital cities tend to include people drawn from all parts of the country and consequently they can often be used as a representative population.

Because of the absence of local data, reference standards based on American children have often been used worldwide and in most developing countries, including Iran. However, due to differences in environmental (e.g., dietary habits) and genetic factors in different parts of the world, the distributions of BP measurements are different. Hence, the application of the American norms can be misleading and BP measurements in children should be compared with local normative BP data [1, 6, 17, 21].

Figure 2 compares the BP measurements for children from Tehran, which was proposed as representative of Iran, with the data available in the Second Task Force 1987 report on BP control in children [5, 22]. The 50th percentiles of systolic and diastolic BP measurements for Iranian boys and girls are higher than for their American counterparts. However, the 95th percentiles of systolic and diastolic BP measurements are lower than the 95th percentiles in the 1987 report, except for the systolic BP measurements of girls.

These findings imply that an Iranian child whose BP measurements are lower than our 50th percentile is classified above the average level if the American norms are used. A similar finding was noted by Tümer et al. [6]. However, those Iranian children whose systolic or diastolic BPs are "high" (>95th percentile) are not classified as high when the American data are used (except for the systolic BP of girls). In contrast, all the 95th BP percentiles of Turkish children, as observed by Tümer et al. [6], and the 95th percentile of systolic BP of

Iranian girls are higher than American norms. Hence, Turkish children whose BP measurements are lower than 95th percentiles are diagnosed as high according to the American references. The same applies for the systolic BP of Iranian girls. Task Force values were based on nine different populations, including blacks and Mexican Americans. They used the first BP reading and not the average of two reading as in our study.

In conclusion, this study supports the hypothesis that regional differences, eating habits, difference in morphometry, and other cultural factors may account for differences in BP levels during childhood. Therefore, every population needs to use its own normal standards to define a measured BP level in childhood. The BP measurements of Iranian school children may be evaluated using the standards presented in this study.

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