BLOOD PRESSURE DISTRIBUTION AND DETERMINANTS OF HIGHER LEVELS OF BLOOD PRESSURE IN JAPANESE RURAL ADOLESCENTS

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The blood pressures (BP) and anthropometric values of 1,014 Japanese rural school children aged 12–17 years old were measured at one-year interval. The strongest correlation for systolic BP (SBP) was weight and for diastolic BP (DBP) it was age. Larger values of weight, body mass index, triceps skinfold thickness and smaller increment of height showed significant discriminative powers in differentiating the subjects who had been above the age-sex specific 80th percentile value (H-H group) from those who had been below the 20th percentile value (L-L group) for both SBP and DBP. Subjects with a family history of hypertension (FHH) had higher SBP than those without a FHH, and were more prevalent in H-H group for SBP. These results indicate that larger body size and more mature stature are determinants of higher levels of BP during adolescence, and that FHH affects SBP only in this period.

CONSIDERABLE attention has been focused on the variation and the time course of blood pressure (BP) levels in childhood. Many epidemiological studies have shown that growth, maturation and proportion of body-build are closely related to the distribution of BP in the young.^{1–5} Both genetic and environmental factors also affect BP levels.^{4–9} Higher levels of BP in childhood tend to be maintained throughout life and may result in essential hypertension in adulthood.^{1–3,10–11} But, there is still controversy as to the determinants of BP levels in the young.^{1–3,12–14} In addition, little is known about ethnic differences.^{1–3,15–16}

Key words:

Blood pressure
Adolescence
Anthropometric values
Family history of hypertension

The aim of this study is to examine the factors contributing to BP levels during adolescence in Japanese rural school children and students with respect to anthropometric variables and family history of hypertension (FHH). The factors influencing the BP trends were examined at a one-year interval.

SUBJECTS AND METHODS

All school children and students of Yoshida junior and senior high schools in Ehime, Japan were included in this study. Yoshida area is one of the average Japanese provinces in western part of Shikoku Island, where agriculture is the chief industry.

This study consisted of two surveys. The first survey (n = 1426; 877 boys and 549 girls) was carried out in October and November, 1984 and

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TABLE I THE RESULTS RECORDED ON THE SECOND SURVEY

	Age	Height (cm)	Weight (kg)	SBP (mmHg)	DBP (mmHg)
Boy	12	153 ± 8.6	44.3 ± 9.2	99 ± 9.7	60 ± 9.0
	13	159 ± 7.5	48.1 ± 10.1	104 ± 9.3	61 ± 9.4
	14	165 ± 6.1	53.9 ± 9.3	107 ± 11.2	64 ± 9.0
	15	168 ± 5.8	56.8 ± 10.1	108 ± 11.6	70 ± 7.8
	16	169 ± 6.0	59.0 ± 8.3	110 ± 11.0	71 ± 8.0
	17	170 ± 5.6	60.2 ± 8.2	111 ± 12.0	71 ± 8.6
Girl	12	152 ± 5.4	45.5 ± 7.6	99 ± 8.6	60 ± 8.0
	13	155 ± 4.9	49.8 ± 8.8	101 ± 10.6	63 ± 8.0
	14	156 ± 5.2	50.4 ± 6.7	101 ± 10.6	64 ± 7.2
	15	157 ± 4.9	52.0 ± 7.1	104 ± 10.2	69 ± 7.9
	16	157 ± 4.8	52.5 ± 7.7	106 ± 8.9	68 ± 8.4
	17	156 ± 5.1	51.7 ± 7.4	104 ± 10.0	68 ± 8.1

Values given represent mean ± SD.

Abbreviations: SBP = systolic blood pressure; DBP = diastolic blood pressure.

one year later the second survey (n = 1530; 931 boys and 599 girls) followed. Height without shoes, weight in light clothing, triceps skinfold thickness (TSF), length and circumference of right upper arm and BP (systolic BP (SBP) and diastolic BP (DBP)) were recorded in each survey. The relationships between BP, age, sex, anthropometric values and FHH were examined in the second survey. One thousand and fourteen subjects (617 boys and 397 girls) participated in the both surveys. BP was set up in age-sex specific quintiles in each survey. The subjects who remained in the top (H-H group) (n = 99, for SBP; n = 70, for DBP) and in the bottom (L-L group) (n = 76, for SBP; n = 53, for DBP) of the quintile rank on both surveys were subgrouped. The differences of anthropometric values and FHH between H-H group and L-L group were examined to clarify factors which affect BP trends.

After the subjects had been sitting for at least 5 min in quiet examination room, BP was measured with mercury sphygmomanometer in the right arm by physicians, who had been trained using educational video-TV program made by Dr. Kahn et al in Emory University. A cuff of an appropriate width (9 or 13 cm) was used according to the circumference of right upper arm. The fourth phase of Korotkoff sounds was regarded as DBP. Heart rate (HR) was measured for 30 seconds. Measurements of BP and HR were taken twice and the means were subsequently analyzed.

Parents, grandparents and siblings of the parents were questioned about their health conditions by questionnaires. If any of them had been hypertensive, a score was given to the subject according to the degree of kinship, namely, score 4 for each parent, score 2 for each grandparent and score 1 for each sibling of each parent. The scores were added for each subject. When the total score was 8 and more, the subject was considered to have a FHH (n = 127; 74 boys and 53 girls). When the total score was 0 and no family history of stroke or myocardial infarction was found, the subject was considered to have no FHH (n = 248; 154 boys and 94 girls). The subject whose total score was between 1 and 7 or had been incompletely questioned was excluded from this study.

Statistical analyses were carried out with Wilcoxon's rank sum test, one way analysis of variance, simple and multiple regression analysis, discriminant analysis, Chi-square test and the contingency table.

RESULTS

Table I shows the results recorded at the second survey. Both SBP and DBP showed a progressive rise with age until 16 years old. In 15–17 year old adolescents, the increases in SBP and DBP were small and irregular (SBP for boys, $F = 3.70$, $p < 0.05$; SBP for girls and DBP for both sexes, not significant). Although most anthropometric values were positively correlated

TABLE II VARIABLES ASSOCIATED WITH BLOOD PRESSURE IN BACKWARD ELIMINATION MULTIPLE REGRESSION ANALYSES

Sex	Systolic blood pressure			Diastolic blood pressure		
	variables	STD.B	contribution	variables	STD.B	contribution
Boy	Weight	0.434***		Age	0.360***	
	Heart rate	0.141***	0.253	Weight	0.162***	0.222
	Age	0.118***		Heart rate	0.068*	
				TSF	0.062	
Girl	Weight	0.261***		Age	0.344***	
	Heart rate	0.253***		Heart rate	0.139***	
	Age	0.125**	0.215	Weight	0.114**	0.170
	Circum.	0.106				

Table shows the variables which are left in the multiple regression equation with height, weight, TSF, circumference of right upper arm, heart rate and age as independent variables. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Abbreviations: Circum = circumference of right upper arm; STD.B = standardized regression coefficient; TSF = triceps skinfold thickness.

TABLE III DISCRIMINANT ANALYSES BETWEEN H-H AND L-L GROUPS

		Height	Weight	BMI	TSF	HR	ΔHt	ΔWt
SBP								
Mean	H-H group	164 cm	60.5 kg	22.36 kg/m ²	10.7 mm	78/min	1.4 cm	2.0 kg
	L-L group	157 cm	47.3 kg	19.08 kg/m ²	7.6 mm	73/min	2.0 cm	1.5 kg
Distance#		0.89	1.85	1.35	0.82	0.13	0.35	0.05
Success (%)#		66.3	73.1	73.7	62.9	53.7	62.3	56.0
Significance*		0.01	0.01	0.01	0.01	ns	0.05	ns
DBP								
Mean	H-H group	162 cm	57.2 kg	21.81 kg/m ²	10.0 mm	80/min	1.1 cm	1.7 kg
	L-L group	160 cm	50.3 kg	19.65 kg/m ²	7.1 mm	71/min	1.8 cm	1.4 kg
Distance#		0.14	0.88	0.80	0.70	0.26	0.63	0.06
Success (%)#		63.4	69.1	72.4	65.9	61.8	64.2	53.7
Significance*		ns	0.01	0.01	0.01	0.05	0.05	ns

Distance: generalized distance between the two groups. #: adjusted for age and sex. *: significance of discriminant function (F) by F-test.

Abbreviations: BMI = body mass index; TSF = triceps skinfold thickness; HR = heart rate; ΔHt , ΔWt = increment of height and weight during a year.

to levels of BP, the strength of correlation varied with age and sex. Backward elimination multiple regression analysis, with SBP or DBP as a dependent variable and with height, weight, TSF, circumference of right upper arm, HR and age as independent variables, revealed that age, weight and HR were significantly related to SBP and DBP in both sexes (Table II). Among these independent variables, the strongest correlate for

SBP was weight and for DBP it was age in both sexes.

Table III shows the results of discriminant analysis performed between H-H group and L-L group. Concerning SBP, the subjects in H-H group had significantly higher values of height, weight, body mass index and TSF (Wilcoxon's rank sum test, each, $p < 0.01$) than those in L-L group. These anthropometric values, adjusted

Fig.1. Percent distribution of age-sex specific quintile ranks for SBP in subjects with and without a FHH. Open column shows subjects without a FHH and lined column shows subjects with a FHH. I = lowest quintile rank, II = lower quintile rank, III = middle quintile rank, IV = higher quintile rank, V = highest quintile rank.

Fig.2. Percent distribution of age sex specific quintile ranks for DBP in subjects with and without a FHH. Open column shows subjects with a FHH and lined column shows subjects without a FHH. Abbreviations; as in figure 1.

for age and sex, successfully separated the H-H group from L-L group. Weight and body mass index showed stronger discriminative powers than others. An increment of height during a year also showed a significant discriminative power, but an increment of weight during a year failed to separate H-H group from L-L group. The value of increment of height during a year was larger in L-L group than in H-H group, which seemed to indicate that the subjects in L-L group remained in less mature state. Concerning DBP,

Fig.3. Percent prevalence of FHH in H-H group and L-L group for SBP and DBP. Open column shows subjects without a FHH and lined column shows subjects with a FHH. Oblique lined column shows subjects who were unable to define to have or not to have a FHH.

the subjects in H-H group had significantly higher anthropometric values except for height (each, $p < 0.01$) than those in L-L group.

The subjects with a FHH had significantly higher SBP than those without a FHH (for boy, 113 ± 13.5 (SD) mmHg vs 107 ± 11.5 mmHg, $p < 0.01$; for girls, 108 ± 10.4 mmHg vs 104 ± 9.8 mmHg, $p < 0.05$), while age, height, weight and HR were similar. The DBP was not different between the subjects with and without a FHH (for boys, 68 ± 9.7 mmHg vs 66 ± 10.4 mmHg; for girls, 66 ± 9.7 mmHg vs 64 ± 9.1 mmHg). Again, backward elimination multiple regression analysis was performed in subjects with a FHH and in those without a FHH. The results showed that FHH was correlated to SBP (STD.B = 0.150 for boys, $p < 0.05$; 0.203 for girls, $p < 0.01$) but was not correlated to DBP.

Figure 1 shows the percent distribution of age-sex specific quintile ranks for SBP by FHH. Lower ranks were more prevalent in subjects without a FHH and higher ranks were more prevalent in subjects with a FHH. The difference of distribution between the 2 group was significant ($p < 0.01$) when analyzed with contingency table. But, for DBP, the difference of distribution of quintile ranks was not significant between the subjects with a FHH and those without a FHH (Fig. 2).

To clarify whether or not a FHH affect BP trends, we examined the percent prevalence of FHH in H-H and L-L groups (Fig. 3). Concerning SBP, there were 14 subjects with a FHH and 8 subjects without a FHH in H-H group, while there were no subjects with a FHH and 15 subjects without a FHH in L-L group. FHH was more prevalent in H-H group than in L-L group

for SBP (Chi-square test, $p < 0.01$). The prevalence of FHH was not different between H-H group and L-L group for DBP.

DISCUSSION

The results obtained in the present study indicate that larger body size and more mature stature determine the higher levels of BP and that FHH affects only SBP.

Our data are very similar to those reported by Woynarowska et al¹⁷ in mean values and in age-BP relationships. But, in general, the mean values of both SBP and DBP in this study are lower than those reported in other countries^{1,18-19} and are between the 10th and the 25th percentiles of the norm recommended by Task Force on Blood Pressure Control in Children.²⁰ The discrepancies may be due in part to actual differences among the populations, although the methodological biases might have influenced the actual differences. However, our findings that both SBP and DBP increase with age, especially during early adolescence are consistent with other studies. In addition, yearly incremental changes in BP become smaller in the late adolescence, particularly in girls.

Concerning "tracking" of BP, there are several reports indicating that taller, heavier, more obese and more mature children tend to maintain their higher BP rank order.^{12,21-24} Similar results were obtained from the present study, where the BP was measured at a one-year interval. Coincidence of BP levels during such a short interval may express the stability of BP. Whether the subjects in H-H group in the present study will become hypertensive adults or not is the question to be answered in future.

Several factors can be attributed to familial aggregation of BP. There are some convincing data showing that the genetic contribution explains most of the familial resemblance of BP.^{7,25} The interesting finding observed in the present study is that only SBP was higher in the subjects with a FHH than in those without a FHH. Levine et al²⁶ showed that a statistically significant genetic variance was detected only for SBP in twins at 6 months of age. On the other hand, Hohn et al¹⁵ and Grim et al²⁷ showed that genetic influences affected both SBP and DBP in subjects aged 10-17 years and 14-17 years. Therefore, we assume that genetic influences affect at first SBP and subsequently DBP. Although the mechanisms of how genetic influ-

ences affect BP levels are complex and uncertain, one of the probable phenomena is that subjects with a FHH have higher stroke volume than those without a FHH, because the major factor which affects SBP is stroke volume of left ventricle in the young.²⁸

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