Blood Pressure Tracking in Japanese Adolescents

Five-year Follow-up in Hisayama, Japan

Junichi WADA, M.D., Kazuo UEDA, M.D.,
Moriyuki TAKESHITA, M.D.,* Tatsuru SHIKATA, M.D.,
Ichiro FUJII, M.D., Toshiro YANAI, M.D., Yutaka HASUO, M.D.,
Yutaka KIYOHARA, M.D., Noriya OKUMIYA, M.D.,
Hideo KAWANO, M.D., *and* Teruo OMAE, M.D.**

SUMMARY

Blood pressures (BPs) were measured with standardized sphygmomanometers in 434 Japanese boys and girls living in the town of Hisayama. Simultaneously, data on pulse rate, weight and height were obtained. Out of the original 434 subjects, data were obtained repeatedly for 5 years in 280 subjects. BP levels were significantly correlated with weight in those aged 14–15 and also 19–20 years, but correlation coefficients were small. During the 5-year period, the mean systolic and diastolic blood pressure (SBP & DBP) increased significantly in both sexes, but the increments were greater in boys. Both SBP and DBP at 14–15 years of age were significantly correlated with data taken 5 years later for both sexes, and subjects with a higher initial BP (more than 90th percentile of the distribution) tended to have a higher BP after 5 years. SBPs after 5 years were independently correlated with initial SBP levels and changes in QI (D-QI) in both sexes. On the other hand, DBPs after 5 years were independently correlated with initial DBP levels and height for boys, and initial DBP levels and D-QI for girls.

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THE relationship of blood pressure (BP) in children to the development of adult essential hypertension is poorly understood. Studies on adult general populations have demonstrated that an initial BP may provide clinical-

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From the Second Department of Internal Medicine, Faculty of Medicine, Kyushu University, Fukuoka, Japan.

* Kyushu Rosai Hospital. ** National Cardiovascular Center.

Address for reprint: Junichi Wada, M.D., Second Department of Internal Medicine, Faculty of Medicine, Kyushu University, Fukuoka 812, Japan.

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ly useful data for predicting risk of later occurrence of hypertension.[1),2)] Previous studies have examined the time course of BP during childhood (Muscatine,[3),4)] Tecumseh[5)] and Bogalusa.[6)] The results indicate that initial BP levels, body weight and compositional changes are the most important predictors of subsequent BP levels. While the time course of changes in BP of children among various racial populations due to the differences in somatic growth are of special interest, little is known of the time course of BP changes in Japanese children. We have measured longitudinal changes in BP of adolescents during a 5-year period, and have assessed its relationship to body measurements.

Materials and Methods

The study population consisted of all third grade junior high school children aged, 14–15 years, residing in Hisayama, Japan. The geographic situation and characteristics of the town have been described in reports of the Hisayama study.[7),8)] From 1974 to 1977, a total of 434 children (232 boys and 202 girls) participated in the screening examination. Data on height, weight, pulse rate, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were collected. The standing height was measured with subjects barefoot in the anthropometric plane. The weight was measured with subjects clothed in sports wear and shoeless on a metric balance scale. The Quetelet index (QI = weight / height^2) was also calculated as a body mass index. Pulse rate was counted with the subject in a sitting position for 30 sec before BP measurements. BP was taken with standard mercury sphygmomanometers with the cuff size of 12 cm × 22 cm. The subjects were seated and after a 5-min rest, a single recording of BP was obtained from the right arm. DBP was recorded at the time of disappearance of Korotkoff sounds. Out of the original 434 subjects, 134 boys and 146 girls returned for a second examina-

Table I. Subjects of the Study

First Examination			Second Examination		
14-15 y.o. (initial)			19-20 y.o. (5-yr later)		
	Boys	Girls		Males	Females
1974	58	62	1979	42	42
1975	58	42	1980	26	26
1976	60	56	1981	35	45
1977	56	42	1982	31	33
Total	232	202	Total	134	146

Table II. Comparison of the Initial Data between the Lost Population and Follow-up Cohort

	Boys		Girls	
	Lost Population	Follow-up Cohort	Lost Population	Follow-up Cohort
N	98	134	56	146
Age (y.o.)	14.6 ± 0.5	14.5 ± 0.5	14.5 ± 0.5	14.5 ± 0.5
SBP (mmHg)	114.1 ±12.9	113.6 ±13.0	110.4 ±14.7	112.7 ±12.9
DBP (mmHg)	63.7 ±11.2	61.3 ±10.7	62.6 ±10.5	64.3 ± 9.6
Height (m)	1.62± 0.08	1.63± 0.05	1.55± 0.07	1.55± 0.05
Weight (kg)	50.1 ± 7.2	52.0 ± 6.9	47.6 ± 6.4	49.8 ± 6.1
QI	19.0 ± 1.8	19.5 ± 2.1	19.8 ± 2.0	20.7 ± 2.2

tion from 1979 to 1982, when they were 19–20 years of age (Table I). The examination included measurements of height, weight and BP, which were repeated by the identical procedures mentioned above. There were no significant differences in the mean values of initial age, SBP, DBP, height and weight between subjects lost to follow-up and those whose subsequent data were available after 5 years (follow-up cohort, Table II). Pearson's simple correlation and Student's t-test were used for descriptive analysis, and multiple regression analysis was used to correlate anthropometric variables and BP measurements (SAS user's guide: Statistics 1982 edition). Values of $p<0.05$ were considered to be statistically significant.

Results

The mean values and standard deviations of BP and anthropometric variables for the whole population at the age of 14–15 years are shown in Table II. Height and weight were greater for the boys, and the QI and pulse rate were higher in the girls. Mean BP values were 114/62 mmHg in boys and 112/64 mmHg in girls. There was no significant difference in mean values of BPs between boys and girls, even after adjustment for weight and height. Pearson's correlation coefficients were calculated to determine the association between BPs and anthropometric variables at the age of 14–15 years (Table III). BPs were significantly correlated with height, weight and QI, although values of the coefficients were small. SBP had a positive correlation with pulse rate in girls but not in boys, while DBP and pulse rate were positively correlated in both sexes. Multiple regression analyses were made to obtain the most significant determinants of BP. Height, QI and pulse rate were selected as independent variables (Table IV). The QI was an im-

Table III. Correlation Coefficients of BP with Height, Weight, QI and Pulse Rate (PR), Whole Population Aged 14–15 Years

	Boys (N=232)		Girls (N=202)	
	SBP	DBP	SBP	DBP
Height	0.15*	0.11	0.23**	0.24**
Weight	0.30**	0.24**	0.32**	0.29**
QI	0.29**	0.23**	0.24**	0.20**
PR	0.06	0.13*	0.23**	0.32**

* $p<0.05$, ** $p<0.01$.

Table IV. Multiple Regression Coefficients, BP and Other Variables, Whole Population Aged 14–15 Years

Boys (N=232)

SBP	Standardized Coefficients	DBP	Standardized Coefficients
QI	0.267**	QI	0.210**
Height	0.124	PR	0.137*
PR	0.068	Height	0.097
R^2	0.100	R^2	0.077

Girls (N=202)

SBP	Standardized Coefficients	DBP	Standardized Coefficients
QI	0.262**	PR	0.357**
PR	0.266**	Height	0.259**
Height	0.252**	QI	0.229**
R^2	0.182	R^2	0.221

PR=pulse rate; R^2=determinant coefficient.
* $p<0.05$, ** $p<0.01$.

portant predictor for both SBP and DBP in both sexes, and pulse rate was also related to DBP in both sexes. The comparisons of mean BP values and anthropometric measurements between the initial survey and the second examination (in the follow-up cohort) are shown in Table V. Over a 5-year period, height and weight significantly increased for both sexes. The increases were greater in boys than in girls. This seems to be due to the delayed growth spurt in boys. During this period, SBP and DBP increased significantly in both sexes. It is important to note that the BP elevation was greater in boys.

To examine the consistency of BP levels recorded at 5-year intervals, we divided the subjects into 2 groups: (1) subjects above the 90th percentile of the

Table V. Comparison of BPs and Anthropometric Variables, Initial Survey and 5 Years Later, Follow-up Cohort

	Boys (N=134)		Girls (N=146)	
	initial	5-yr later	initial	5-yr later
Age (y.o.)	14.5± 0.5	19.8± 0.4	14.5± 0.5	19.0±70.4
SBP (mmHg)	113.6±13.0	130.8±12.6	112.7±12.9	117.9±10.1
DBP (mmHg)	61.3±10.7	73.3±11.5	64.5± 9.6	72.7± 7.7
Height (cm)	163.3± 5.5	169.3± 5.4	155.1± 4.8	156.2± 4.8
Weight (kg)	52.0± 6.9	60.1± 7.4	49.8± 6.1	50.9± 6.3
QI	19.5± 2.1	21.0± 2.4	20.7± 2.2	20.9± 2.3

Variables are means±SD.

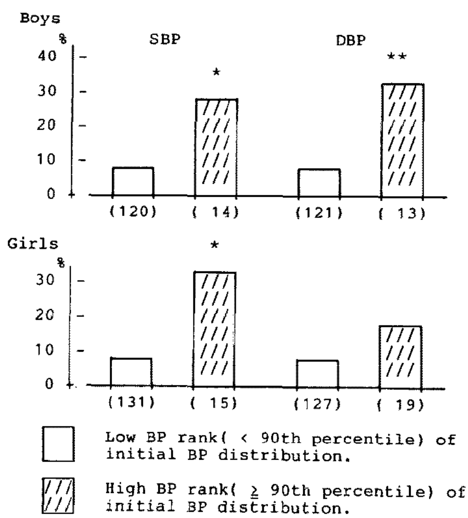

Fig. 1. Blood pressure tracking during the 5-year period, follow-up cohort. * $p<0.05$, ** $p<0.01$.

initial distribution and (2) those below the 90th percentile. Fig. 1 indicates the proportion of subjects from each group with BP levels above the 90th percentile of the 5-year follow-up distribution. Approximately 30% or more of boys with SBP or DBP levels above the 90th percentile in the initial survey had SBP or DBP levels in the top decile of the distribution 5 years later. For girls, this effect was more prominent for SBP (more than 30%) than for DBP (about 15%). Subjects with SBP or DBP levels below the 90th percentile for the initial survey had a much lower incidence of BP values above the 90th percentile after 5 years.

Pearson's simple correlation coefficients were used to examine the relationships of variables estimated at the initial survey and follow-up with BP

Table VI. Correlation Coefficients between BP Levels after 5 Years and Other Variables, Follow-up Cohort

Boys (N=134)	SBP	DBP
BP (initial)	0.35**	0.33**
Height (initial)	0.01	0.15
Weight (initial)	0.18*	0.19*
QI (initial)	0.21*	0.14
Height (5-yr later)	−0.06	0.09
Weight (5-yr later)	0.26**	0.19*
QI (5-yr later)	0.31**	0.16
Girls (N=146)	**SBP**	**DBP**
BP (initial)	0.32**	0.33**
Height (initial)	0.18*	0.10
Weight (initial)	0.16	0.07
QI (initial)	0.07	0.01
Height (5-yr later)	0.17*	0.14
Weight (5-yr later)	0.26**	0.18*
QI (5-yr later)	0.20*	0.12

* $p<0.05$, ** $p<0.01$.

values (Table VI). The SBP or DBP values measured at 5-year intervals were correlated significantly; the correlation coefficients were 0.35 for SBP and 0.33 for DBP in boys and 0.32 for SBP and 0.33 for DBP in girls. Body weight at the follow-up examination was significantly associated with both SBP and DBP levels for both sexes, whereas the body weight at the initial examination was positively related to SBP or DBP in boys only. For girls, height at the initial survey was correlated significantly with SBP levels, but after 5 years the correlation was weaker than that of body weight.

The predictive factors for determining both SBP and DBP after 5 years were assessed by using stepwise multiple regression analyses (Table VII). The SBP, DBP, pulse rate, height, QI at initial survey and changes in height (D-height) and QI (D-QI) during the 5-year period were selected as independent variables. Initial SBP and D-QI during this interval were significant determinants of SBP levels in both sexes. However, only about 17% of the variability in SBP was explicable by these six variables. On the other hand, initial DBP was also a significant determinant of DBP levels in both sexes. D-QI values for girls were weakly correlated with DBP levels; however a significant correlation was not observed in boys. The determinant coefficients for DBP by six variables were 0.14 in boys and 0.17 in girls.

Table VII. Determinant Factors of BP Levels, Stepwise Multiple Regression Analyses, Follow-up Cohort

Boys (N=134)

SBP	Standardized Coefficients	DBP	Standardized Coefficients
BP (initial)	0.299**	BP (initial)	0.315**
D-QI	0.223**	Height (initial)	0.183*
QI (initial)	0.118	D-Height	0.080
D-Height	−0.027	QI (initial)	0.061
Height (initial)	−0.010	PR (initial)	0.052
PR (initial)	0.002	D-QI	0.046
R^2	0.178	R^2	0.138

Girls (N=146)

SBP	Standardized Coefficients	DBP	Standardized Coefficients
BP (initial)	0.301**	BP (initial)	0.383**
D-QI	0.242**	D-QI	0.203*
Height (initial)	0.129	D-Height	0.086
QI (initial)	0.073	Height (initial)	0.042
PR (initial)	−0.043	QI (initial)	0.005
D-Height	−0.040	PR (initial)	−0.043
R^2	0.169	R^2	0.166

PR=pulse rate; R^2=determinant coefficient.
* $p<0.05$, ** $p<0.01$.

Discussion

In our cross-sectional data, the BPs of boys and girls aged 14–15 years were positively correlated with height, weight, QI and pulse rate. This evidence seems to suggest that children who are heavy and/or tall for their age tend to have a higher BP. Although such a positive relationship has already been studied by others, these results are somewhat perplexing. The data of Londe[9] from a study on 735 boys and 738 girls from 4 through 15 years of age indicated a relationship of SBP with weight, but not with height, while the age-adjusted DBP was only related to weight in girls. Lauer and co-workers[10] showed a significant relation of both SBP and DBP with weight and height in 4,829 school children aged 6 through 18 years old. Higgins et al[11] reported significant correlations of age-adjusted SBP with height in 10–14-year-old boys and 5–14-year-old girls.

Our results from multiple regression analyses revealed that the QI was the most important determinant of both SBP and DBP for both sexes. In

addition, height was a significant predictor for both SBP and DBP in girls. Several groups of investigators [12)-14)] emphasized that height is an important contributor to BP in these age groups. These findings imply that BP is correlated with weight in children aged 4 through 15 years, and perhaps also with height in those past 9 or 10. During childhood, body dimensions increase with age, and the variability of the correlation between BP and body-mass may be reflections of changes in body-mass with age. Furthermore, BP was more closely correlated with body size around the age of puberty. Past the age of 15 years, the vast majority of the population is sexually mature and correlations between height and BP may be negligible. From this point of view, the longitudinal and prospective observation of the relationship between BP and somatic growth is more important.

We found that the degree of increments in both SBP and DBP from 15 through 20 years of age was more prominent in boys than girls, and that body weight increased more markedly in boys than girls during this period. However, both SBP and DBP at age 20 were significantly correlated with weight for both sexes. In addition, the correlation of BP with the increase in QI was also observed. A similar result was noted in a study on BP changes over 5 years in 14–15-year-old white adolescents;[15)] the mean SBP increased significantly only in boys, while the rate of increase of DBP was greater in boys than in girls. This indicates that the compositional change in body size has a significant effect on BP. However, it was uncertain whether increasing adiposity is more related to BP elevation than increased muscle mass, since our data suggest that large rates of growth in boys are likely to be associated with the delayed spurt in maturation of boys during this interval.

Another important hypothesis is that BP itself may be an indicator of adult BP. The relationship between BP at 14–15 years of age and that at 19–20 years was also significant when estimated either by simple correlation or multiple regression analysis. Similar correlations have been observed repeatedly in the adult population,[1),16)-19)] and it has been termed the tracking phenomenon. This can be particularly important during adolescence, since it may be predictive of hypertension in adulthood. Zinner et al[20)] reported that BP levels in children aged 2 to 14 years were significantly correlated with subsequent BP levels over the period of 4 years, and suggested that the stratification of BP in relation to peer groups began in childhood. Voors et al[6)] and Webber et al[21)] showed in the Bogalusa heart study that there was a close correlation between initial BP measurements and subsequent BP measurements in childhood, and emphasized that quantification of the extent to which children's BP goes up was important for early diagnosis and prevention of hypertension. However, the tracking correlation tends to de-

crease as the time between measurements increases. In the Muscatine study, Clarke et al[3] indicated that BP did not track well because correlation coefficients decreased with time. Rosner et al[22] also observed this phenomenon, particularly in children under 15 years. If the follow-up period is too short, this may be attributed to the phenomenon of regression toward the mean, wherein deviated values of biologic variables such as BP tend to regress to the group mean on repeated measurements.

Our data must be interpreted with caution. The study population consists of a relatively small sample size, and BP was obtained from a single measurement. Since the BP varies occasionally, the tracking correlation between two single measurements of casual BP deviated from the true tracking correlation between the mean BP obtained from a large number of measurements at each evaluation. In addition, a number of factors not analyzed in this study correlate with BP and may play a role in determining long-term BP changes. Most of the variability in BP remained unexplained in the present analyses, and the biological variability attributable to the prior BP level and the D-QI during the 5-year period accounted for around 20% of the total variance. However, from the perspective of tracking, we found a significant correlation between two measurements at 5-year intervals in Japanese children. However, no difference in the tracking phenomenon between Japanese and the Western children was identified. Before a direct comparison of the results obtained from various studies, the differences in study designs such as subject composition and intervals and methods of BP measurements must be carefully considered.

The hypothesis that elevated BP in youth can predict hypertension in later adult life is not new.[16)–18)] Hypertension may be the most important risk factor for cardiovascular diseases, especially in the Japanese adult population. If children's elevated BPs at initial evaluation do invariably remain at this level, a continuous observation of subsequent BP level should be made, even though BP levels do not reach the range of actual hypertension.

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