Shimane J. Med. Sci. Vol. 5, pp. 144–150, 1981

Percentile Values of Blood Pressure in Childhood, and Anthropometric Measurements in Normotensive and Hypertensive Children

The Shimane Heart Study

(blood pressure/percentile values/anthropometric measurements)

TOSHIKAZU NISHIO, KATSUTOSHI ABE, MASAKAZU SAITO, NORIYUKI HANEDA, KOJI WATANABE, SUSUMU OKAHATA, and CHUZO MORI

Department of Pediatrics, Shimane Medical University, Izumo 693, Japan
(Received August 20, 1981)

The percentile values of blood pressure were calculated in 1,546 healthy Japanese children aged 4 to 17 years. Systolic blood pressure was increased with chronological age and correlated with body length, body weight, lean body weight, body surface area, upper arm length and upper arm circumference.

Anthropometric values of 119 hypertensive children were also measured. In these children there was a tendency toward obesity, as the following anthropometric values were larger in these children; body weight, body surface area, ponderosity, upper arm circumference and skin fold thickness.

Essential hypertension plays a considerable role in the epidemiology of the vascular disease of adults in Japan. Although numerous studies have been done on the pathogenesis and epidemiology of hypertension, there are few studies which followed populations prospectively, that is, from the onset of hypertension.

In 1978, the Shimane Heart Study was undertaken in an attempt to clarify the pathogenesis of hypertension which may begin in childhood (1–5). For research of childhood hypertension, it was necessary to establish normal ranges of blood pressure in children at various ages.

This paper reports the percentile values of blood pressure in randomly sampled children, and the relationship between blood pressure and anthropometric values in normo- and hypertensive children.

MATERIALS

Randomly Sampled Groups

A total of 1,546 children aged 4 to 17 were randomly sampled from several kindergartens, primary schools, and junior and senior high schools. All are living in Izumo, Shimane Prefecture, a country city of moderate size and population in Japan.

Hypertensive Groups

One hundred and nineteen children with hypertension were studied. Blood pressure of all school children was examined in three junior high schools and one senior high school in Izumo, and hypertensive children were selected according to the following criteria : 135 mmHg or over in systolic and/or 80 mmHg or over in diastolic pressure. Secondary hypertension was excluded by thorough physical examination, urinalysis, ECG and echocardiography.

Control groups were 266 children of the same school with a normal blood pressure. Details of the study population are shown in Tables I and II.

TABLE I. *Number of Randomly Sampled Children, by Age and Sex*

Age (years)	Boys	Girls
4–5	147	140
6	234	230
9	212	203
12	100	139
15	81	60
Total	774	772

TABLE II. *Number of the Hypertensive and the Randomly Sampled Children, by Age and Sex*

Age (years)		Hypertensives	Normotensives
12–14	Boys	53	68
	Girls	51	58
15–17	Boys	14	81
	Girls	1	59
Total	Boys	67	149
	Girls	52	117

METHODS

The following examinations were performed for all the children who participated in the studies :

(1) Questionnaire for family history of hypertension, cerebral apoplexy, coronary infarct, obesity and diabetes mellitus.

(2) Anthropometric measurements of body length, body weight, chest circumference, anteroposterior and right to left diameters of thorax, skin fold thickness, upper arm length and circumference.

(3) Blood pressure.

(4) Urinalysis for protein, sugar and sediment.

(5) Serum total and HDL cholesterol.

(6) Hemoglobin concentration of venous blood.

(7) Electrocardiography, vectorcardiography and echocardiography.

The skin fold thickness was measured at a median point on the lateral side

of the right upper arm (Triceps), and right subscapular point. A Harpenden caliper with 10 g/mm^2 pressure was used for the measurements (6).

The blood pressure was measured with the children in a sitting position, in the right upper arm, by mercury sphygmomanometer. The width of manchette was 9 and 12 cm for children of 9 years or under and 12 years or over, respectively. Diastolic pressure was obtained at the 4th point of Swan. Measurements were performed three times and the lowest systolic pressure was adopted as the blood pressure of individual children. Percentile values were calculated from a table of the cumulative frequency distribution.

Lean body weight (LBWt) was calculated from body weight (BWt), triceps skin fold thickness (T) and upper arm circumference (UAC), using the following equation as a convenient approximation ;

$$\text{LBWt}=\text{BWt}\times\frac{\text{AA}-\text{FA}}{\text{AA}}$$

$$\text{AA (Arm area)}=\frac{\text{UAC}^2}{4\pi}$$

$$\text{FA (Fat area)}=\frac{\text{T}}{2}(\text{UAC}-\frac{1}{2}\pi\text{T}).$$

In the present paper, ponderosity means log (body weight/body length^3).

RESULTS

Percentile Values of Blood Pressure in Randomly Sampled Groups

Percentile values and curves of systolic and diastolic blood pressure are shown in Table III and Figs. 1 and 2. Median values of systolic pressure increased gradually with chronological age. In all ages except for 15 year old children, the boys had a slightly higher blood pressure than did the girls.

TABLE III. *Percentile Values of Blood Pressure in Randomly Sampled Children*

Age (years)		Numbers	Percentile values of blood pressure (mmHg)							
			Systolic				Diastolic			
			50	90	95	97	50	90	95	97
4–5	Boys	147	91	101	106	108	46	61	62	63
	Girls	140	91	105	110	111	50	62	64	66
6	Boys	234	92	102	108	111	52	64	69	70
	Girls	230	92	105	110	112	54	66	69	70
9	Boys	212	104	116	120	122	61	72	74	76
	Girls	203	101	116	121	123	61	72	74	75
12	Boys	100	112	127	132	134	62	72	76	78
	Girls	139	115	130	135	137	63	74	80	81
15	Boys	81	121	140	142	145	64	76	81	82
	Girls	60	114	129	133	134	71	81	84	88

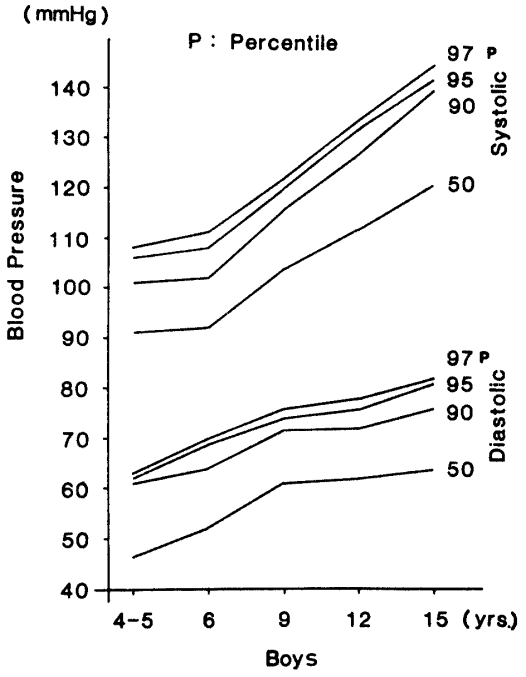

Fig. 1. Percentile curves of blood pressure in randomly sampled boys.

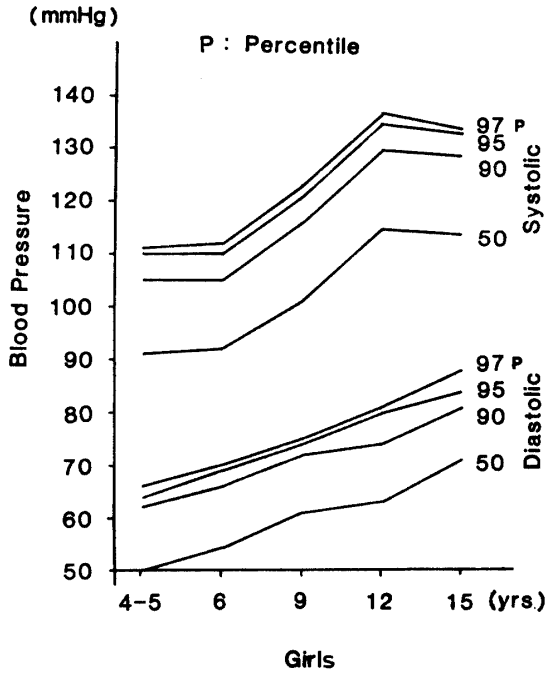

Fig. 2. Percentile curves of blood pressure in randomly sampled girls.

Relationship between Systolic Blood Pressure and Anthropometric Values in Randomly Sampled Groups

Systolic pressure was closely correlated with the following anthropometric values (Table IV) : body length, body weight, lean body weight, body surface area, upper arm length and upper arm circumference. Correlation between systolic pressure and skin fold thickness was poor in both sexes.

TABLE IV. *Relationship between Systolic Blood Pressure and Anthropometric Values in Randomly Sampled Children*

Anthropometric values	Boys			Girls		
	Correlation coefficients	Regression equations** A	B	Correlation coefficients	Regression equations** A	B
Body length	0.74	0.53	33.2	0.60	0.44	44.4
Body weight	0.73	0.76	79.1	0.67	0.78	77.5
Lean body weight	0.72	0.89	82.7	0.66	1.26	77.8
Body surface area	0.71	33.7	66.8	0.54	34.9	65.3
Upper arm length	0.71	2.1	46.8	0.65	2.4	38.5
Upper arm circumference	0.71	2.9	43.9	0.62	2.8	45.1
Skin fold thickness*	0.07	0.84	88.0	0.35	0.50	88.1

* Triceps+Subscapular ** Blood pressure=A×Anthropometric values+B

Comparison of Anthropometric Values between the Hypertensive and the Normotensive (Control) Children

As shown in Table V, body weight, body surface area, ponderosity, upper arm circumference and skin fold thickness were significantly higher in the hypertensive children. In addition, the following values were higher in hypertensives ; body length and upper arm length in boys, and lean body weight in girls, respectively.

TABLE V. *Comparison of Anthropometric Values between Hypertensive and Randomly Sampled Children*

Anthropometric values		Hypertensives	Normotensives	Test for difference (p)
Blood pressure	♂	140±9	117±13	< 0.01
	♀	136±8	116±11	< 0.01
Body length	♂	164.7±8.0	158.8±12.4	< 0.01
	♀	154.5±5.6	152.9±6.6	NS†
Body weight	♂	58.3±13.1	49.3±11.4	< 0.01
	♀	51.8±10.5	7.0±8.3	< 0.01
Lean body weight	♂	40.0±8.7	37.6±9.9	NS†
	♀	30.1±4.4	28.4±4.5	< 0.05
Body surface area	♂	1.61±0.20	1.48±0.23	< 0.01
	♀	1.48±0.15	1.40±0.15	< 0.01
Ponderosity*	♂	1.11±0.07	1.08±0.05	< 0.01
	♀	1.14±0.07	1.11±0.05	< 0.01
Upper arm length	♂	33.7±3.2	32.6±3.5	< 0.05
	♀	31.1±1.6	30.8±2.0	NS†
Upper arm circumference	♂	26.3±3.8	24.0±2.8	< 0.01
	♀	25.1±3.2	23.7±2.6	< 0.01
Skin fold thickness**	♂	23.4±12.8	18.7±6.8	< 0.01
	♀	35.7±15.0	30.2±11.3	< 0.05

* log (Body weight/length^3) ** Triceps+Subscapular † Not significant

Family History of Hypertension

No significant differences were noted in the family history between the hypertensive and the normotensive children.

DISCUSSION

The percentile values of blood pressure are used universally for the epidemiological studies of hypertension in children (7). These values have not been established for Japanese children.

In the present study, the blood pressure increased with age, and the sex difference was apparent in those over 15. This tendency was also reported

in the United States (7) and Japan (8). In general, the blood pressure of children was slightly lower in the Japanese than in the Americans (7). The differences were several mmHg in systolic and 10 mmHg in diastolic, respectively. This means that the blood pressure increases more slowly in Japanese than in American children.

Blood pressure of normal subjects was reported to be correlated with body length, body weight, body surface area, upper arm length, upper arm circumference and ponderosity (9—11, 14). Except for ponderosity, similar results were obtained in our study. In children, both blood pressure and these anthropometric values were positively correlated with chronological age. Therefore, further statistical methods such as a multi-variate analysis may be necessary to clarify the relationship among these variants.

The anthropometric values were compared between the hypertensive and the normotensive children. Body weight, body surface area, ponderosity, upper arm circumference and skin fold thickness were significantly larger in the former than in the latter. These results show that hypertensive children have a tendency toward obesity. Similar findings were reported in several papers from the United States (12 —14), but there are no such data on Japanese children.

Although the familial aggregation of hypertension in children has been reported (10, 11, 15, 16), the present study showed no such a tendency. This discrepancy may be due to a lack of uniformity in the data, as the family history was obtained by questionnaire.

This study was supported in part by grants from the Science and Technology Agency of Japan.

REFERENCES

1) Mori, C., Nishio, T., Saito, M., Soeda, T., Nakao, Y., Fuseya, Y., and Abe, K. (1979) Left ventricular hypertrophy in children—The Shimane Heart Study. Royal Society of Medicine International Congress Series, No. 9, 99—104
2) Saito, M., Mori, C., Nishio, T., Soeda, T., and Abe, K. (1978) Normal values of echocardiography in pediatrics. I. Left ventricular volume (LVMV). The Shimane Heart Study. *Shimane J. Med. Sci.* **2**, 63—69
3) Nishio, T., Mori, C., Saito, M., Soeda, T., Abe, K., and Nakao, Y. (1978) Left ventricular hypertrophy in early hypertensive children ; Its importance as a risk factor for hypertension. The Shimane Heart Study. *Shimane J. Med. Sci.* **2**, 157—166
4) Mori, C., Abe, K., Nishio, T., Saito, M., Soeda, T., Tomita, Y., and Nakao, Y. (1980) Basic study for computer analysis of the pediatric electrocardiographic voltage with the echocardiographically determined left ventricular muscle volume. *Jpn. Circ. J.* **44**, 855—858
5) Abe, K., Mori, C., Nishio, T., Saito, M., Haneda, N., Tomita, Y., and Soeda, T. (1980) Statistical comparison of echocardiographically determined left ventricular size estimated by XY digitizer system between normotensive and early hypertensive children. The Shimane Heart Study. *Shimane J. Med. Sci.* **4**, 127—133
6) Edwards, D. A. W., Hammond, W. H., Healy, M. J. R., Tanner, J. M., and Whitehouse, R. H. (1955) Design and accuracy of calipers for measuring subcutaneous tissue thickness. *Br. J. Nutr.* **9**, 133—143
7) Blumenthal, S. (1977) Report of the task force on blood pressure control in children. Standards for children's blood pressure. *Pediatrics* **59**, 802—807

8) Okamura, T. (1981) Blood pressure of children in Tohoku District. *Nippon Shonika Gakkai Zasshi* **85**, 650–657 (in Japanese)
9) Voors, A. W., Webber, L. S., Frerichs, R. R., and Berenson, G. S. (1977) Body height and body mass as determinants of basal blood pressure in children—The Bogalusa Heart Study. *Am. J. Epidemiol.* **106**, 101–108
10) Morrison, J. A., Khoury, P., Kelly, K., Mellies, M. J., Parrish, E., Heiss, G., Tyroler, H., and Glueck, C. J. (1980) Studies of blood pressure in school children (ages 6–19) and their parents in an integrated suburban school district. *Am. J. Epidemiol.* **111**, 156–165
11) Higgins, M., Keller, J., Moore, F., Ostrander, L., Metzner, H., and Stock, L. (1980) Studies of blood pressure in Tecumseh, Michigan. I. Blood pressure in young people and its relationship to personal and familial characteristics and complications of pregnancy in mothers. *Am. J. Epidemiol.* **111**, 142–155
12) Johnson, A. L., Cornoni, J. C., Cassel, J. C., Tyroler, H. A., Heyden, S., and Hames, C. G. (1975) Influence of race, sex and weight on blood pressure behavior in young adults. *Am. J. Cardiol.* **35**, 523–530
13) Lauer, R. M., Connor, W. E., Leaverton, P. E., Reiter, M. A., and Clarke, W. R. (1975) Coronary heart disease risk factors in school children : The Muscatine Study. *J. Pediatr.* **86**, 697–706
14) Voors, A. W., Foster, T. A., Frerichs, R. R., Webber, L. S., and Berenson, G. S. (1976) Studies of blood pressure in children, ages 5–14 years, in a total biracial community. The Bogalusa Heart Study. *Circulation* **54**, 319 –327
15) Zinner, S. H., Levy, P. S., and Kass, E. H. (1971) Familial aggregation of blood pressure in childhood. *N. Engl. J. Med.* **284**, 401 –404
16) Londe, S., Bourgoignie, J. J., Robson, A. M., and Goldring, D. (1971) Hypertension in apparently normal children. *J. Pediatr.* **78**, 569–577