Studies on blood pressure in school children by means of rejection ellipse methods

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I Introduction

Many studies on blood pressure have been conducted in the fields of public health and of clinical medicine. However, very few systematic studies have been undertaken in children. Because blood pressure in children is the precursor of blood pressure in adults, it is suggested that if the blood pressure is measured continuously from childhood to adulthood the many factors which have not been elucidated about the presence of hypertension in adults may be explained.

The measurement of blood pressure in school children at T Elementary School in Yokohama City began in 1976. The results of these measurements which were obtained over a period of four years, are described in the present report.

II Methods

1. Subjects and term of measurement of blood pressure

The measurement of blood pressure in all school children of T Elementary School in Hodogaya-ku, Yokohama City began in 1976. Blood pressure was then monitored in all students each of the next three years. Blood pressures were measured from May 10th to June 20th each of the four years. Blood pressures were measured on six separate days for each subject. All measurements were taken between 1 p.m. and 3 p.m.

Subjects were school children enrolled in first, second, and third grade during 1976. Hereafter those students in first grade during 1976 will be referred to as Group A, those in second grade as Group B, and those in third grade as Group C. The sample of students who were monitored all four years consisted of 139 students in first grade (Group A), 64

Table 1 Sample Size By Sex and Group, Across Time

Sex	Group	1976	1977	1978	1979	Number of subjects monitored - all four consecutive years
Male	A*	84	89	84	87	64
	B*	109	103	102	101	81
	C*	100	97	88	87	68

Female	A*	104	98	103	100	75
	B*	112	99	101	98	75
	C*	87	87	86	86	64

A* indicates students in 1st grade during 1976

B* indicates students in 2nd grade during 1976

C* indicates students in 3rd grade during 1976

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males and 75 females; 156 students in second grade (Group B), 81 males and 75 females; and 132 students in third grade (Group C), 68 males and 64 females (Table 1).

2. Measurement of blood pressure

Prior to blood pressure measurement subjects were laid on their back and instructed to remain quiet. Blood pressure was obtained over the right arterial brachialis by means of auscultatory technique. A Riva-Rocci type sphygmomanometer was used. The cuff width of the sphygmomanometer was nine cm. Blood pressures were measured twice, with two to three minutes between measurements. The lower measurement was taken as the value for this investigation.

3. Statistical analysis

The mean systolic and diastolic blood pressure were calculated by sex and grade. Then the rejection ellipses at the level of significance of ten per cent were drawn. The variation of the rejection ellipses were studied by year.

The values of the variables for the rejection ellipses were calculated by the following formula: X represents the diastolic blood pressure and Y represents the systolic blood pressure. Blood pressures were measured N times. a_{11} , a_{12} , and a_{22} are given by

$$\begin{aligned} a_{11} &= \Sigma X^2 - (\Sigma X)^2 / N \\ a_{12} &= \Sigma XY - (\Sigma X \Sigma Y) / N \\ a_{22} &= \Sigma Y^2 - (\Sigma Y)^2 / N \end{aligned}$$

Then, the squares of half of the long axis is given by

$$\left\{ a_{11} + a_{22} + \sqrt{(a_{11} - a_{22})^2 + 4a_{12}^2} \right\} F_{N-2}^2 (0.10) \times (N+1) / N(N-2)$$

The squares of half of the short axis is given by

$$\left\{ a_{11} + a_{22} - \sqrt{(a_{11} - a_{22})^2 + 4a_{12}^2} \right\} F_{N-2}^2 (0.10) \times (N+1) / N(N-2)$$

Hence, the long axis and the sort axis are obtained from the squares of half of each value. An angle of inclination of the long axis is given by

$$\tan 2\theta = \frac{-2a_{12}}{a_{22} - a_{11}}$$

An area is given by

$$2\pi \sqrt{a_{11}a_{22} - a_{12}^2} \times F_{N-2}^2 (0.05) \times (N+1) / N(N-2)$$

In using this formula, N subjects who's blood pressures were measured during four consecutive years were represented by the number of times that blood pressures were measured, thus N times.

III Results

The mean systolic blood pressure and diastolic blood pressure for all students measured each year, divided by grade was compared with the means from only those students monitored all four years, again divided by grade. The results are shown in Table 2. Few differences between all subjects of each grade and only those subjects who's blood pressure was measured all four years were shown in either males or females for any given year.

Hereafter the results of only subjects who's blood pressures were measured all four years are described. Comparing the mean systolic and diastolic blood pressure between males and females the former were lower the latter

with the following exceptions. The mean systolic blood pressure of Group B in 1976, the mean diastolic blood pressure of Group B and Group C during 1977, and the systolic and diastolic blood pressures of Group C during 1978 and 1979 exhibited the opposite trend.

The blood pressures of Groups A, B, and C in 1976 were compared. The results obtained were as follows. As the grade of the students increased the mean systolic and diastolic blood pressure increased in both males and females except for the systolic blood pressure of Group B females. This trend was also noted in 1977, 1978, and 1979.

Variation in blood pressure was noted for each group across time. The mean systolic blood pressure for Group A did not change

over the four years except in 1978 when it decreased. The mean diastolic blood pressures for Group A in 1976 and 1977 were similar. The mean diastolic blood pressure for Group A increased in 1978 and again in 1979 for both males and females (Table 2).

The upper and lower limits of systolic blood pressure by rejection ellipses for Group A showed the following trend; as the grade of the student increased the systolic blood pressure decreased for both males and females. The upper limit of diastolic blood pressure by rejection ellipse for Group A in males was lowest during 1977 and in females was highest during 1976. The lower limit of diastolic blood pressure was the lowest for Group A in both males and females during 1976. (Table 3 and Figures 1 and 2)

Table 2 Mean Blood Pressure By Sex and Group, Across Time
(Systolic Blood Pressure/Diastolic Blood Pressure)

Sex	Group	1976	1977	1978	1979
Male	A*	a*107.4/53.4	a 106.1/53.7	a 103.5/55.7	a 107.1/56.8
	A	b*107.4/52.8	b 106.4/52.6	b 102.6/54.9	b 106.7/56.4
	B*	a*110.9/56.0	a 104.6/61.5	a 104.3/56.9	a 110.2/60.8
	B	b*111.0/56.0	b 104.5/61.5	b 103.7/57.0	b 110.0/60.7
	C*	a*115.2/62.7	a 108.9/61.6	a 111.9/60.8	a 118.9/62.8
	C	b*115.6/62.3	b 109.6/61.5	b 113.0/61.3	b 120.2/63.6
	A*	a*111.4/56.8	a 109.0/55.9	a 104.3/57.5	a 108.9/57.9
	A	b*112.1/56.6	b 109.4/56.9	b 105.4/57.8	b 109.0/58.0
	B*	a*111.1/60.2	a 104.3/60.7	a 103.4/58.0	a 112.0/61.8
Female	B	b*110.5/60.8	b 104.7/60.7	b 103.8/58.1	b 112.1/62.1
	C*	a*115.4/64.0	a 111.6/60.8	a 111.5/60.8	a 117.3/61.2
	C	b*115.7/64.6	b 111.1/61.1	b 111.0/61.1	b 116.6/61.3

A* indicates students in 1st grade during 1976

B* indicates students in 2nd grade during 1976

C* indicates students in 3rd grade during 1976

a* all subjects monitored that year

b* only subjects monitored all four years

Mean systolic blood pressure for Group B in males during 1977 and 1978 was lower than that of Group B during 1976 and Group B during 1979. Mean diastolic blood pressure in males for Group B was lower during 1976 and 1978 than during 1977 and 1979. The trend in females was similar to that in males for systolic blood pressure. However the mean diastolic blood pressure in females did not vary a great deal across time. (Table 2)

Using rejection ellipses the upper limit of systolic blood pressure for Group was lowest

during 1977 in males and during 1978 in females.

The lower limit for both males and females was highest during 1976. The upper limit of diastolic blood pressure by rejection ellipse for Group B did not vary a great deal across time in males. However in females the upper limit was highest during 1979. The lower limit of diastolic blood pressure for Group B in males was lowest during 1976. There was no great difference across time in females. (Table 3 and Figures 3 and 4)

Table 3 Upper and Lower Limits of Blood Pressure by Rejection Ellipses

		Male				Female			
		1976	1977	1978	1979	1976	1977	1978	1979
Group A									
Systolic Blood Pressure	Upper Limit	126.1	123.4	122.5	125.5	133.3	128.5	126.2	130.5
	Lower Limit	88.4	89.5	83.0	87.7	90.8	90.2	84.5	87.5
Group A									
Diastolic Blood Pressure	Upper Limit	79.5	69.0	73.5	76.5	84.5	75.5	76.5	76.5
	Lower Limit	26.3	36.5	36.2	36.5	29.0	38.7	39.5	39.8
Group B									
Systolic Blood Pressure	Upper Limit	131.5	125.0	129.2	132.5	128.5	129.5	122.4	136.5
	Lower Limit	90.5	84.0	78.0	87.2	92.7	85.5	85.5	87.5
Group B									
Diastolic Blood Pressure	Upper Limit	83.0	81.0	79.0	80.0	80.5	82.5	76.5	87.0
	Lower Limit	29.0	42.5	35.0	41.0	41.0	39.0	40.0	38.0
Group C									
Systolic Blood Pressure	Upper Limit	134.0	126.0	135.0	142.0	135.5	132.0	132.0	138.0
	Lower Limit	97.5	93.5	91.0	98.8	95.5	90.0	90.0	95.2
Group C									
Diastolic Blood Pressure	Upper Limit	92.0	82.5	82.0	82.5	83.5	84.3	80.0	80.5
	Lower Limit	33.5	41.0	40.5	44.5	45.5	38.0	42.5	42.5

Fig. 1 The rejection ellipses at 10% significant level on the blood pressure measured all four years in males for Group A

Fig. 2 The rejection ellipses at 10% significant level on the blood pressure measured all four years in females for Group A

Fig. 3 The rejection ellipses at 10% significant level on the blood pressure measured all four years in males for Group B

Fig. 4 The rejection ellipses at 10% significant level on the blood pressure measured all four years in females for Group B

Mean systolic blood pressure for Group C in males was highest in 1979. Mean systolic blood pressure for Group C in females was lowest during 1977 and 1978. There were few differences in mean diastolic blood pressure across time in males or females.

Using rejection ellipses the upper limit of systolic blood pressure for Group C in males was lowest during 1977. There was no great difference across time in females. The lower limit of systolic blood pressure for Group C was lowest in males during 1978 and in females during 1977 and 1978. The upper limit of diastolic blood pressure by rejection ellipse for Group C in males was highest during 1976. There was no great difference in females across time. The lower limit of diastolic blood pressure for Group C was lowest in males during 1976 and in females during 1977. (Table 3 and Figures 5 and 6)

Fig. 5 The rejection ellipses at 10% significant level on the blood pressure measured all four years in males for Group C

IV Discussion

The blood pressure of school children has been measured during four consecutive years beginning in 1976. Rejection ellipses were used to analyze the results.

Blood pressures have previously been analyzed by rejection ellipse methods as illustrated in papers by Hirao (1957), Akiyama (1960), Shishido et al. (1965), and Ariizumi (1975). No study using rejection ellipses methods for analysis of blood pressure has been conducted on school children. In this study a ten per cent level of significance was used for the rejection ellipses. The area of the rejection ellipses was too wide for practical use when a five per cent level of significance was used (Ogihara, 1981).

The mean, upper limit, and lower limit of systolic and diastolic pressures did not show an increase as the grade in school of the

Fig. 6 The rejection ellipses at 10% significant level on the blood pressure measured all four years in females for Group C

student increased. It was interesting that these results showed differences when compared with such customary results as represented by the paper of Koshiishi (1960). In the Koshiishi study (1960) systolic blood pressure increased greatly in the second or third grades. The diastolic blood pressure increased greatly in the third or fourth grade. Furthermore, females demonstrated a greater increase than did males. It must be noted that the investigation of Koshiishi (1960) did not follow up the same subjects but was a sectional survey.

Matsuura (1969) reported the normal range of blood pressure in children to be from 90 to 180 mmHg for systolic blood pressure. Okamoto (1959) performed a study on the range of blood pressure using the means of rejection limit method and five per cent level of significance. Okamoto (1959) advocated that the upper limits were 130 mmHg from six to eight years of age and 135 mmHg from nine to eleven years of age. The lower limit for systolic blood pressure was 90 mmHg at each grade. The upper limit for diastolic blood pressure was 90 mmHg and the lower limit was 45 mmHg. Londe et al. (1971) said that the upper limit of normal for systolic blood pressure was 130 mmHg and for diastolic blood pressure was 90 mmHg. Ōkuni (1977) reported that hypertension was a systolic blood pressure higher than 130 mmHg or a diastolic blood pressure higher than 85 mmHg.

This study suggests an upper limit for systolic blood pressure of 135 mmHg and a lower limit of 95 mmHg. This study suggests an upper limit for diastolic blood pressure of 85 mmHg and a lower limit of 35 mmHg. These values are comparable to the results of the former investigator's reports. Therefore,

it has been shown that a ten per cent level of significance is more useful than a five per cent level of significance for rejection ellipses.

V Summary

The blood pressure of school children was measured during four consecutive years using the rejection ellipse method for analysis of blood pressure. the results obtained were as follows:

1. The mean, upper limit, and lower limit of rejection ellipses for systolic and diastolic blood pressures of subjects did not increase as grade in school increased.
2. The authors propose that the normal range of the blood pressure for school children is 95 – 135 mmHg for systolic blood pressure and 35 – 85 mmHg for diastolic blood pressure.
3. For rejection ellipses ten per cent is a more useful level of significance than is five per cent.

References

- Akiyama Fusao (1960) : Ketsuatsu (Blood pressure), Katsunuma et al. ed., The Method of Mass Examination of Public Health, 1st ed., 849-870, Ishiqaku Shuppan Co. (Tokyo).
- Ariizumi Syozi (1975) :Yōzi No Ketsuatsuchi No Hendo Ni Kansuru Kenkyu (The study on the variation in the blood pressure of healthy infant), The Yokohama Medical Journal, 26 (5,6), 151-168.
- Hirao Masaharu (1957): Nihonjin No Ketsuatsu No Tokeigakuteki Kenkyu (Statistical studies on Japanese Blood Pressures), The Journal of Life Insurance Medicine, 55 (2), 1-29.
- Londe, S. et al. (1971): Hypertension in

- apparently normal children, J. Pediat., 78, 569.
- Matsuura Shoichi (1969): Tōhoku Chiho Gakudo Ketsuatsu Ni Tsuite, Dai Ippo 2-3 Tōhoku-ku Gakudo Niokeru Ketsuatsu No Tokeigakuteki Kansatsu (On the blood pressure of school children living in Tōhoku District, Report 1. Statistical studies on blood pressures of school children living in some Tōhoku Districts), Shonika Rinsho, 22 (11), 1443-1448.
- Okamoto Yoshiaki (1959): Shoni Ketsuatsu No Sokutei Kijun Nikansuru Kenkyu, Dai San Pen Shoni No Seijo Ketsuatsuchi Nitsuite (Studies on blood-pressure determination in childhood, Part III. The normal values of blood-pressure in childhood), Acta Ped. Jap., 63, 1793-1797.
- Ogihara Arata (1981): Kikyaku Daen Niyoru Ketsuatsu Kanri Nitsuiteno kenkyu (Studies on the administration of blood pressure using the mean of rejection ellipse method), The Yokohama Medical Journal (was contributed).
- Ōkuni Nobuhiko (1977): Kodomo No kōketsuatsu (Hypertension in childhood), The Journal of the Japan Medical Association, 78 (4), Hypertension, No. 8, 8-11.
- Shishido Masao et al. (1965): Kikyaku Daen Niyoru Ketsuatsu No Hendo No Kento (Studies on the variation of blood pressure by means of rejection ellipse methods), The Yokohama Medical Journal, 16 (1,2), 28-33.

〔和文抄録〕

学童の血圧の棄却楕円による検討

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著者らは4年間連続測定した学童427名(男213名, 女214名)の血圧について, 棄却楕円を用いて検討した結果, 次の成績を得た。

1. 最大血圧, 最小血圧の平均値および棄却楕円の上限, 下限は学年とともに高くならなかった。

2. 学童の血圧の正常範囲を最大血圧では135～95mmHg, 最小血圧では85～35mmHgとすることを提唱した。

3. 棄却楕円の有意水準は5%より10%にした方が有効である。