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Twelve-year Tracking of Blood Pressure in Korean School Children: the Kangwha Study

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Abstract

Longitudinal data from different populations have shown different degrees of tracking of blood pressure (BP). To examine BP tracking in Korean school children, 219 of 430 children (100 males, 119 females) who were 6 years old in 1986 in Kangwha County, Korea have been examined annually up to 1997 in the Kangwha Study. BP was measured twice with standard mercury sphygmomanometers and the average of the two measurements was used for the level of BP. Diastolic BP were measured at the fourth Korotkoff sound. Tracking was examined using a time-lag correlation analysis and McMahan's tracking index tau, which indicates the proportion of variation attributable to tracking apart from the natural growth component. As well the jackknife method was used to obtain the confidence interval of tau. Correlation coefficients between systolic BP from age 6 to 17 ranged from 0.39−0.54 for males and 0.44−0.57 for females. Taus for systolic BP were 0.875 (95% CI: 0.803−0.947) and 0.900 (95% CI: 0.809−0.991) in males and females, respectively. Correlation coefficients between diastolic BP from age 6 to 17 ranged from 0.28−0.47 for males and 0.14−0.47 for females. Taus for diastolic BP were 0.983 (95% CI: 0.897−1.000) and 0.800 (95% CI: 0.717−0.883) in males and females, respectively. These findings showed strong evidence for BP tracking in Korean school children from childhood to late adolescence.

Key Words: Tracking, blood pressure, children

INTRODUCTION

It is well known that blood pressure (BP) increases consistently from infancy to adolescence.[1-6] Longitudinal observations of BP throughout childhood are important because they determine the relative rank of BP in children and whether or not it has been maintained over time. The persistence of the rank order of BP has been referred to as BP tracking. Longitudinal data from different populations have shown different degrees of BP tracking.[7] These discrepancies may be due to differences in age and characteristics of the study population and/or the analytic methods used.

Since error is expected in the measurement of BP, within-individual variation of BP should be accounted for in the estimation of tracking. Gillman et al. reported that the tracking correlation was substantially increased by correcting for within-individual variation.[8] In order to correct the within-individual variation, two approaches are available. The first is to design a study to measure within-individual variation which could be divided into inter-visit and intra-visit variation. The second approach is to use statistical models which can separate the components of heterogeneity in each individual and for random error. Random effect, growth curve and mixed model are typical examples of these models. Many studies which have examined BP tracking have had limitations in the study design for estimating within-individual variation and relied on time-lag correlation analysis which cannot account for within-individual variation in order to examine BP tracking.[7] In this study, we

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tried to correct within-individual variation by averaging two measurements of BP per visit and by using McMahan's tracking model. The tracking index suggested by McMahan allows an innate increase in BP, controlling for the within-individual variation by using a growth curve model.[9]

The Kangwha Study, formerly known as the Kangwha Children's Blood Pressure Study, has been examining BP changes in school children annually since 1986 and has reported BP tracking in children from age 6 to 11 (1986–1991) using traditional procedures as well as McMahan's method.[10] Even though we confirmed that there was BP tracking during childhood, there was a need to examine the tracking during adolescence in order to show BP tracking from childhood to adult. Since adolescent period include puberty which is characterized with rapid physiological growth and hormonal changes, it is hard to expect that BP tracking during childhood will be maintained during adolescence. The Kangwha study completed the 11th year of follow-up in 1997. The purpose of this study was to examine BP tracking over a 12-year period from childhood to late adolescence.

MATERIALS AND METHODS

This study analyzed the data from a population-based prospective cohort study in Korea, known as the Kangwha Study. In this study, 430 school children (211 males, 219 females) who were in the first grade in 1986 in Kangwha County, Korea, have been followed to measure their BP annually through 1997. A total of 219 children (100 males, 119 females) completed all 12 annual examinations until they reached age 17. Kangwha County is located on a large island at the mouth of the Han River, west of Seoul, and consists of rural villages and a small town.

Methods of BP measurement were described in detail in our previous paper.[10] In summary, standard mercury sphygmomanometers were used with appropriate size cuffs. Two measurements were taken on each occasion every year in similar school surroundings, and the average was used in the analysis. Diastolic BP was measured at the fourth Korotkoff sound.

Two methods were used to examine the presence of tracking. First, we calculated the tracking correlation coefficient matrix using a banded model. In this model, covariance between measurements depends only on the length of the time intervals. Second, McMahan's method was used. The details of McMahan's method were described in our previous paper.[10] In short, McMahan proposed a tracking index tau based on a growth curve model. Tau measures the proportion of variation in BP attributable to tracking distinct from the variation due to growth. The tau ranges from 0 to 1, with 1 corresponding to perfect tracking. We also estimated the standard error of tau by the jackknife method. Additionally, we showed the trends in BP over the 12-year period within quartile groups formed on the basis of the first-year BP to see whether or not the relative ranking of the mean BP among the quartile groups remained in the same group for the 12-year period.

RESULTS

To examine the effect caused by eliminating 211 children who had incomplete data, we compared BP and anthropometric measures at baseline between children with complete follow-up and children who had withdrawn. As shown in Tables 1 and 2, there were no significant differences in systolic and diastolic BP, height, weight, and body mass index between the two groups, suggesting that the elimination of children with incomplete data did not introduce any appreciable bias. The findings were the same in both genders.

Table 3 shows the time-lag correlation coefficients

Table 1. Comparison between Complete Follow-up and Withdrawn Cases in Males

Variable	Follow-up (n=100)		Withdrawn (n=111)	
	Mean	SD	Mean	SD
Height (cm)	118.4	4.9	117.8	5.0
Weight (kg)	21.0	2.7	21.1	3.5
BMI (kg/m^2)	14.9	1.2	15.2	1.7
SBP (mmHg)	97.3	9.2	98.9	10.8
DBP (mmHg)	59.8	7.6	61.7	8.4

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 2. Comparison between Complete Follow-up and Withdrawn Cases in Females

Variable	Follow-up (n=119)		Withdrawn (n=100)	
	Mean	SD	Mean	SD
Height (cm)	117.2	4.6	117.7	4.7
Weight (kg)	19.9	2.4	20.1	2.2
BMI (kg/m^2)	14.5	1.1	14.5	1.1
SBP (mmHg)	96.9	9.6	96.8	11.4
DBP (mmHg)	61.2	7.9	60.0	9.4

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 3. Tracking Correlation Coefficients for Systolic and Diastolic BP from Banded Model

Interval (year)	Male (n=100) SBP	Male (n=100) DBP	Female (n=119) SBP	Female (n=119) DBP
1	0.50	0.47	0.57	0.47
2	0.54	0.36	0.50	0.41
3	0.53	0.35	0.55	0.37
4	0.52	0.37	0.53	0.34
5	0.48	0.44	0.51	0.33
6	0.43	0.40	0.49	0.25
7	0.45	0.38	0.52	0.30
8	0.42	0.38	0.47	0.29
9	0.40	0.32	0.46	0.28
10	0.39	0.39	0.46	0.15
11	0.41	0.28	0.44	0.14

SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 4. McMahan's Tracking Index tau (τ) for Systolic and Diastolic BP by Gender

Gender	BP	Estimate (τ)	95% CI
Male	Systolic	0.875	0.803 – 0.947
	Diastolic	0.983	0.897 – 1.000
Female	Systolic	0.900	0.809 – 0.991
	Diastolic	0.800	0.717 – 0.883

BP, blood pressure; CI, confidence interval.

for systolic and diastolic BP over the 12-year period. The correlation coefficient for systolic BP ranged from 0.39 to 0.54 in males, and from 0.44 to 0.57 in females. For diastolic BP, it ranged from 0.28 to 0.47 in males, and from 0.14 to 0.47 in females. The association became weaker as the time lag between ages increased both in systolic and diastolic BP.

Table 4 shows the estimates of tracking index tau and 95% confidence intervals for systolic and diastolic BP by gender. Tau for systolic BP was 0.875 in males and 0.900 in females, and for diastolic BP tau was 0.983 in males and 0.800 in females. The estimates of tau and their confidence intervals suggest that the estimated proportion of variation attributable to tracking is quite stable.

Fig. 1 shows the mean systolic BP over time within the quartile groups based on the initial BP at age 6 in males. Even though the mean systolic BP of the two middle quartiles were getting closer and showed almost the same level after age 12, it is noteworthy

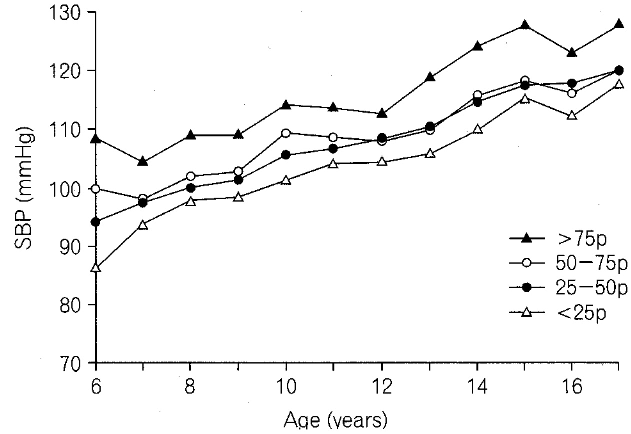

Fig. 1. Change in mean SBP over time within the quartile groups based on the initial BP at age 6 in males.

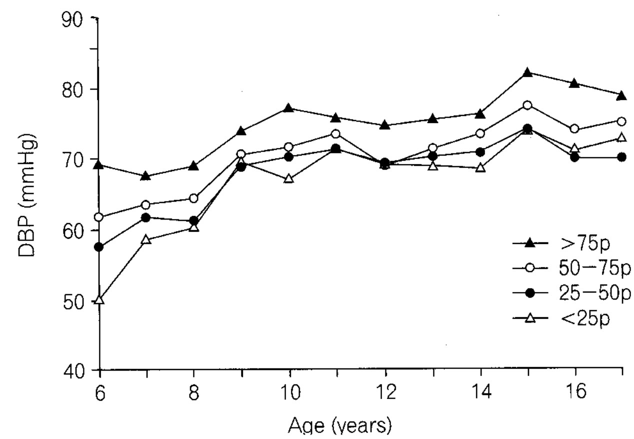

Fig. 2. Change in mean DBP over time within the quartile groups based on the initial BP at age 6 in males.

that the order of mean BP among the quartile groups did not change remarkably. For diastolic BP, the order of mean diastolic BP was well maintained until age 15, but at age 16 and 17 the order changed in the lower two quartiles (Fig. 2).

Fig. 3 and 4 show the mean systolic and diastolic BP in females. For the mean systolic BP, the order of mean BP did not change over the entire period and the female pattern was clearer than in males. For diastolic BP, the order of mean diastolic BP was maintained until age 11, but after that the order changed. The results shown Fig. 1−4 can be taken as a general indication of the existence of a BP tracking phenomenon in children.

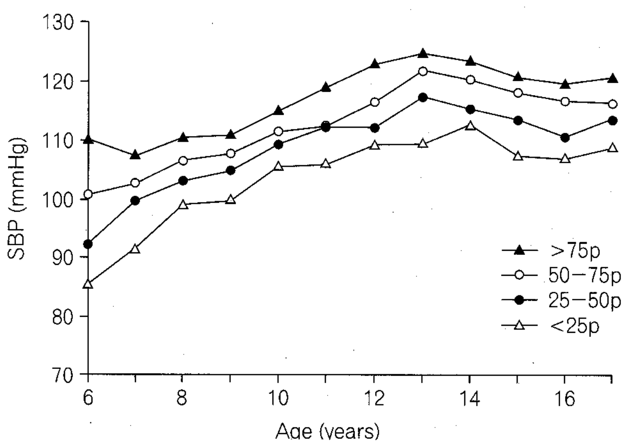

Fig. 3. Change in mean SBP over time within the quartile groups based on the initial BP at age 6 in females.

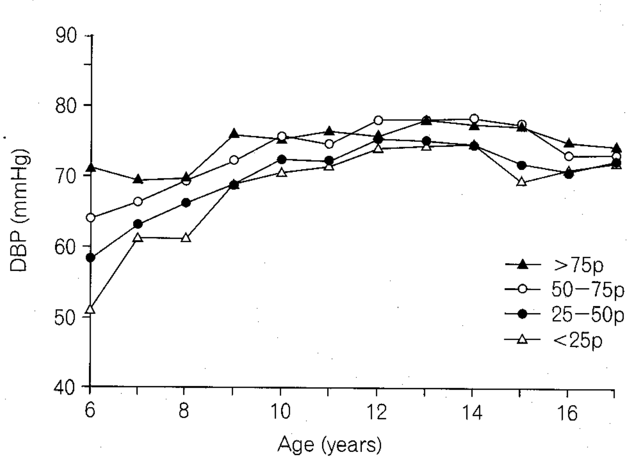

Fig. 4. Change in mean DBP over time within the quartile groups based on the initial BP at age 6 in females.

DISCUSSION

Many studies have examined BP tracking in children and most of them have used time-lag correlation analysis in order to examine tracking.[7] Since the strength of tracking is heavily related to its statistical characteristics, it is important to select the valid statistical methods to examine tracking. Measurement error caused by within-individual variability should be taken into account in the estimation of BP tracking. Gillman et al. proposed the tracking correlation corrected for within-individual variability explained by inter-visit and intra-visit variability.[8] They showed that the number of visits is more important than the number of measurements per visit. In our previous study, the tracking correlation corrected for the intra-visit variability increased up to 1.2 times for systolic and 1.7 times for diastolic blood pressure compared to unadjusted correlation.[11] Since there was only one visit annually in our study, we couldn't estimate the inter-visit variability. Therefore, we used McMahan's method which takes into account inter-visit variability.

For constructing the pattern of tracking correlation in serial measurements of BP, goodness of fit and parsimonious principle have to be considered at the same time. As the number of measurements increase, the general correlation matrix will be no more useful because it is difficult to interpret the trend of tracking. Since the correlation pattern showed some tendency to decrease with an increasing time lag, but not to decrease consistently and exponentially over the entire study period, we selected a banded model for estimating the tracking correlation. Banded model assumes that the covariance between i-th and j-th measurements depend upon the absolute value of (i-j), and not the magnitude of i and j. Therefore, the two covariances are equal if they are calculated from time intervals of the same length.

Among studies which examined BP tracking, some followed children for a long time (more than 10 years), but most studies measured BP only several times during the follow-up period. This study measured the BP of children every year for 12 years, and, therefore, it was possible to show trends in BP over the 12-year period within quartile groups formed on the basis of the first-year BP. With this analysis, we were able to check whether the relative ranking of the mean BPs among the quartile groups remained in the same from childhood to early adulthood. Also, correlation of BP at any interval within the 12-year period could be compared with data from this study. Another important aspect of multiple BP measurements during childhood is that it greatly helps in predicting future hypertension in adulthood.[6] Shear et al. reported that individuals classified as high in BP by multiple measurements were more likely to remain high after 8 years.[12]

Since there have been no other studies reported McMahan tracking index tau, it wasn't possible to compare the degree of tracking with this index. However, when compared to the tracking coefficients reported by other studies which followed children for more than 10 years, the tracking coefficients of systolic and diastolic BP in this study were at similar levels.[1-6,13,14] Thus, our findings provide strong evidence for the continuation of BP tracking from childhood through puberty to late adolescence.

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