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CHANGES OF HEART RATE, BLOOD PRESSURE AND ANTHROPOMETRIC MEASUREMENTS WITH AGE DURING CHILDHOOD

(Heart rate / Blood pressure / Children)

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Heart rate, blood pressure and anthropometric measurements were examined every 3 years, from 6 to 15 yrs, in 1221 children. Heart rate gradually decreased with age (r= -0.47 in boys, and -0.26 in girls), and was negatively correlated with height, body weight and lean body weight. Our data showed significantly positive correlation between heart rate and blood pressure in girls, whereas in boys the positive correlation disappered at the pubertal period because of the influence of sex maturation. High BP tracking group tended to have faster heart rate than low BP tracking group. We concluded that it is valuable to measure heart rate for the prediction of adult hypertension, especially in girls.

Increased heart rate in young adults has been reported to be one of the risk factors for essential hypertension [1]. Similar studies are very few in pediatric fields. If there is significant correlation between heart rate and blood pressure(BP) of children, the increased heart rate in childhood may be a predictive factor for essential hypertension later in life. However, it is difficult in children to estimate the relation between heart rate and BP, because the latter is influenced by many factors. Therefore, we analyzed the changes of heart rate, BP and body size simultaneously. The purposes of our study are as follows ; (1) To establish the normal range of heart rate by age and sex in children and adolescents; (2) To clarify the mutual relation among BP, anthropometric measurements and heart

rate; (3) To investigate the relationship between BP and respiratory variation of heart rate; (4) To compare the heart rate between groups whose BP tracked in the higher and the lower quintile.

MATERIALS AND METHODS

Study populations were 1221 Japanese children in Izumo city, which was located in north-west of Honshu Island, Japan. Each cohort was examined every 3 years, that is, at 6, 9 and 12 yrs in cohorts 1 and 2, and 9, 12 and 15 yrs in cohorts 3 and 4 (Table I). All subjects were healthy and had no cardiac diseases.

Height, body weight, chest circumference and upper arm circumference were measured by conventional methods. Skin fold thickness was determined by Harpenden caliper. Lean body weight (LBW) was calculated from body weight (BW), triceps skin fold thickness (T) and upper arm circumference (UAC), using the following equation as a convenient approximation(2) ;

$$LBW = BW \times (AA-FA)/ AA$$

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

$$FA \text{ (Fat area)} = (UAC-\pi T/2) \times T/2$$

BP was measured in sitting position at right arm by a mercury sphygmomanometer. Cuff size was selected according to UAC (7 cm for UAC less than 16.0 cm, 9 cm for 16.1-22.5 cm and 12 cm for 22.6 cm or more). Systolic and diastolic BP were recorded at 1st and 4th point of Korotcoff sounds, respectively.

Table I. THE NUMBERS OF CHILDREN IN EACH COHORT

Cohorts	Sex	Age at Examination 6y	9y	12y	15y	Total	
1	M	82→				127	
	F	45→					
2	M	53→				93	
	F	40→					
3	M		55→			98	
	F		43→				
4	M		38→			89	
	F		51→				
Total	M	135	228	228	93	684	1221
	F	85	179	179	94	537	

Heart rate was calculated from the mean of 30 RR intervals (RR-mean) on electrocardiogram (Frank lead system).

Respiratory variation was defined as the difference between the slowest and the fastest heart rate calculated from RR interval of the longest and the shortest duration (RR-max and RR-min), respectively. Respiratory variation coefficient (RVC) was calculated by the follow equation;

$$RVC = (RR\text{-}max - RR\text{-}min) / RR\text{-}mean$$

We compared heart rate between the high and the low BP tracking groups defined by Nishio et al [2]. The former group consisted of 10 boys and 22 girls, whose systolic BP remained always below 20th percentile. We used paired Student'st test for statiscal analysis.

RESULTS

(1) Changes of heart rate during childhood (Table II, Fig.1,2)

Heart rate gradually decreased with age, while BP and anthropometric parameters increased. The correlation coefficients between heart rate and age were -0.47 and -0.26 in boys and girls, respectively. From 6 to 12 yrs, there was no significant difference of heart rare between boys and girls. However, at 15 yrs, heart rate was slower in boys than in girls ($p < 0.01$). The slope of decrease of heart rate from 12 to 15 yrs was steeper in boys than in girls ($p < 0.01$).

(2) The mutual relation among heart rate, BP and anthropometric measurements

Heart rate was negatively correlated to height, body weight and lean body weight ($p < 0.01$) (Table III). These correlation coefficients were tended to be higher in boys than in girls. But no significant relationship was observed between heart rate and BP. The correlation coefficients between heart rate and BP in each cohort are shown in Table IV. Cohorts 1 and 2 (3 and 4)

Table II. HEART RATE BY AGE AND SEX (MEAN ± SD)

	6y	9y	12y	15y
Boys	91.3 ± 11.0	82.5 ± 10.4	78.4 ± 10.4	69.6 ± 9.1
Girls	90.0 ± 11.3	81.4 ± 12.2	79.7 ± 9.4	*[76.2 ± 11.8

(beats / min)

* statistically significant ($p<0.01$)

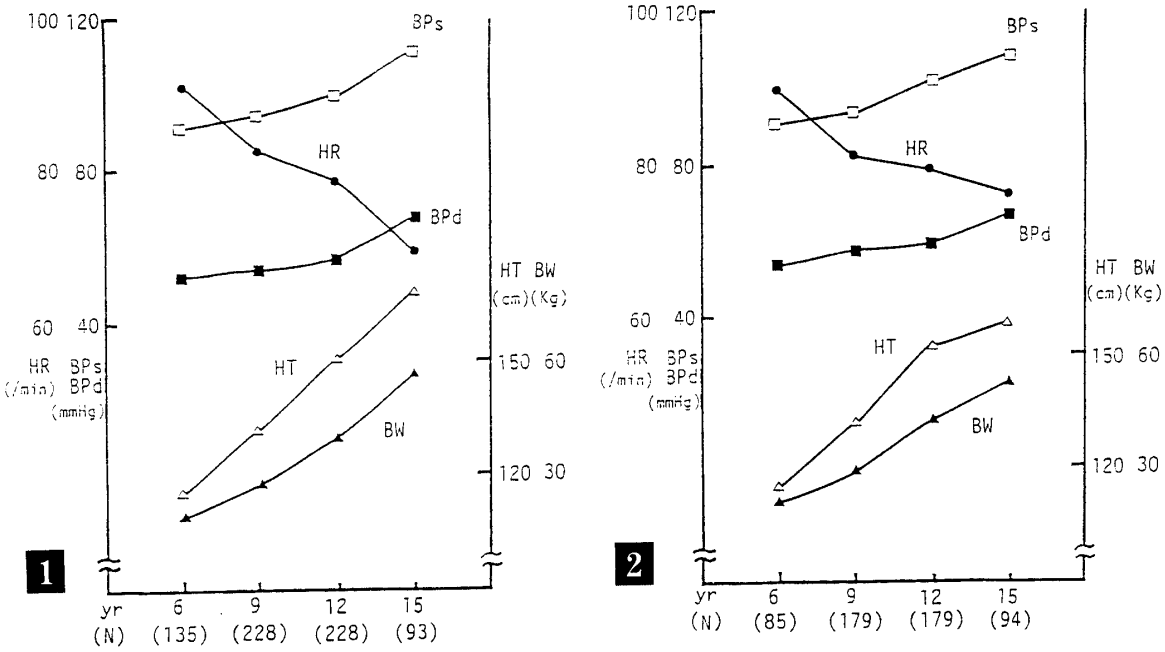

Figure 1. HEART RATE (HR), SYSTOLIC BP (BPs), DIASTOLIC BP (BPd), HEIGHT (HT) AND BODY WEIGHT (BW) WITH AGE IN BOYS

Figure 2. HEART RATE (HR), SYSTOLIC BP (BPs), DIASTOLIC BP (BPd), HEIGHT (HT) AND BODY WEIGHT (BW) WITH AGE IN GIRLS

Table III. CORRELATION COEFFICIENTS BETWEEN HEART RATE AND EACH MEASUREMENTS IN 6-15 YRS-OLD CHILDREN

	Boys (N=684)	Girls (N=537)
Systolic BP	0.03	0.03
Diastolic BP	-0.02	0.04
Height	-0.40*	-0.21*
Body Weight	-0.37*	-0.19*
Lean Body Weight	-0.55*	-0.25*
Age	-0.47*	-0.26*

* statistically significant ($p<0.01$)

Table IV. CORRELATION COEFFICIENTS BETWEEN HEART RATE AND SYSTOLIC AND DIASTOLIC BP IN EACH COHORT

		Cohort 1 + 2	Cohort 3 + 4
Observation Period		6 - 12 y	9 - 15 y
No. of Subjects		Boys 135 Girls 85	Boys 93 Girls 94
Boys	SBP	0.10*	-0.08
	DBP	0.17**	-0.09
Girls	SBP	0.15*	0.23**
	DBP	0.15*	0.11

** statistically significant ($p<0.001$)
* statistically significant ($p<0.05$)

Table V. CORRELATOIN COEFFICIENTS BETWEEN RVC AND AGE, AND EACH PARAMETER

	Boys (n=466)	Girls (n=494)
SBP	-0.03	-0.17*
DBP	-0.11*	-0.06
Height	-0.05	-0.27**
Body weight	-0.09*	-0.27**
Age	-0.08	-0.26**

* statistically significant ($p<0.05$)
** statistically significant ($p<0.01$)

Table VI. THE MEAN VALUES OF HEART RATE IN HIGH AND LOW BP TRACKING GROUPS

Age (yrs)		6	9	12	15
Boys	high BP	**[102.8±10.1	79.7±14.1	74.6±11.9	*[73.4± 5.5
	low BP	94.1±11.6	80.7±13.4	78.0±12.1	64.6± 5.0
Girls	high BP	89.4±10.2	*[84.4± 8.5	85.9± 8.2	*[84.5± 4.6
	low BP	93.4±10.7	74.3± 4.2	78.1±13.6	69.0± 9.9

* statistically significant ($p<0.01$)
** statistically significant ($p<0.005$)

were mixed for statistical analysis because there were no significant differences of the mean between two cohorts. During 6-12 yrs in cohorts 1 and 2, heart rate was positively correlated with both systolic and diastolic BP on both sexes (r = 0.10, 0.17 in boys and 0.15, 0.15 in girls, respectively). These were statistically significant. During 9-15 yrs in cohorts 3 and 4, there were no significant correlations between heart rate and BP in boys, while girls had positive correlation between heart rate and systolic BP (r = 0.23), but not for diastolic BP.

(3) Respiratory variation of heart rate (Table V)

The correlation coefficients between heart rate and RVC were -0.23 in boys and -0.10 in girls. RVC tended to decrease with age in girls (r = -0.26), but not significantly in boys. RVC had significantly negative correlations with systolic BP, height and body weight in girls (r = -0.17, -0.27 and -0.27, respectively), but it was negatively related to diastolic BP and body weight in boys (r = -0.11 and -0.09, respectively).

(4) The differences of heart rate between the high and the low BP tracking groups were significant in 6 year-old boys, 9 year-old girls and 15 year-old boys and girls (Table VI).

DISCUSSION

Previous studies have reported that heart rate decreased with age continuously from birth to adolescence [3]-[6]. The results of our study are in good agreement with these reports. We think that decrease of heart rate is caused by growth of heart muscle. Heart muscle matures with age[8],[22], and cardiac contractility gets stronger. Stroke volume and cardiac output increase along with these events. As the consequence, heart rate levels gradually decrease during childhood and early adolescence and are stabilized in late adolescence, when heart maturation is accomplished.

In the course of heart maturation, sex difference seems prominent. Our study showed that heart rate during 12-15 yrs dropped more steeply in boys than in girls. The similar results were reported by some investigators[6],[12]. These results may indicate that heart maturation occurs earlier in boys than in girls. McGill et al[8] suggested that the presence of androgen receptors may be important in the regulation of heart maturation, as teststerone and adrenal androgens stimulate these receptors and result in heart maturation in boys. In girls, however, heart maturation does not occur until the secretion of adrenal androgen begins at about 14 years of age. Therefore, both heart maturation and decrease in heart rate might occur earlier in boys than in girls.

Many studies have revealed the positive correlation between heart rate and BP in children and adolescents[5],[11], as well as on adults[7],[9],[10]. Our data showed significantly positive correlation between BP (both systolic and diastolic) and heart

rate in 6 to 12 year-old children of both sexes. In the period from 9 to 15 years, girls had significantly positive correlation between heart rate and systolic BP, whereas boys had negative, but insignificant, correlation between heart rate and both systolic and diastolic BP. These results indicate that heart rate during pubertal period is influenced by sex maturation rather than growth. In childhood, physical growth is one of the most important factors for both heart rate and BP. Especially, body weight has the strongest relationship to BP[15]-[17]. Well-growing children tend to have the higher heart rate and BP. In the pubertal period from 14 to 16 years, heart rate gradually drops and BP rises as a normal response to cardiovascular maturation[18]. Therefore, heart rate of boys tends to decrease along with elevation of BP during early adolescence. On the other hand, girls still have positive correlation between heart rate and BP. Schall et al[13] reported that heart rate and BP (both systolic and diastolic) showed a positive association throughout adolescence for females, but not for males. They also reported that females with higher BP had consistently higher pulse rate (PR), while males in the upper percentiles for diastolic BP had higher PR in early adolescence, but lower PR in later adolescence. They found these results in the mixed cross-sectional analysis. It is important that our results were obtained in individuals followed longitudinally. We must follow up the girls with higher heart rate to establish its predictive value for hypertension occurred later in life.

Parasympathetic nervous system activity was measured through the change of R-R interval corrected by heart rate. Respiratory variation of heart rate was reported to reduce with age[19],[20]. Our date in girls were consistent with this tendency. RCV was correlated with systolic BP, height and body weight in girls. But RVC of boys might be influenced by other factors. The changes of RVC and BP with age can be explain by the following findings ; (1) the autonomic nervous system function declines with age, (2) decline of baroreceptor sensitivity leads to compensatory autonomic nervous system response, (3) the plasma norepinephrine level increases, (4) the mean arterial BP increases[21].

In conclusion, heart rate decreases with age from 6 to 15 years in both sexes, but the relationship between heart rate and BP differs between boys and girls. Girls have positive

correlation among heart rate, BP and body mass throughout childhood. We think that it is valuable to measure heart rate for the prediction of adult hypertension, especially in girls.

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