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Key Words

growth;
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An accurate assessment of the physical growth and development of children has attracted more attention from government health officers and pediatricians. Many studies report standard growth for height and weight among Taiwan children.¹⁻⁴ They are based on cross-sectional survey to obtain growth standard curves that are different from the curves obtained longitudinally. It has been pointed out that longitudinal, rather than cross-sectional, growth standards are more effective in assessing individual linear growth, and the difference is particularly apparent during puberty in standards for growth velocity.⁵

In 1966, Tanner *et al.* produced longitudinal standards suitable for clinical use in the British population.^{6,7} Longitudinally-based height velocity charts for North American children were also presented in 1985.⁸

A Longitudinal Study of Growth Patterns in School Children in Taipei Area I: Growth Curve and Height Velocity Curve

Background. It has been pointed out that longitudinal rather than cross-sectional growth standards should be used to assess individual linear growth. The purpose of this study is to investigate the growth characteristics of school boys and girls living in Shih-Pai district in Taipei.

Methods. A defined group of 1,139 healthy school children (570 boys and 569 girls) from the Shih-Pai district of Taipei city were followed longitudinally for 3 to 4 years. Anthropometric measurement of height and weight and physical development in each child were obtained. The annual increments were calculated every 6 months to map the peak height velocity (PHV), height velocity curve (HVC), peak weight velocity (PWV) and weight velocity curve (WVC).

Results. The age at peak velocity was taken as 12.5 years for boys and 10.5 years for girls, and the whole year PHV as 8.0 cm/yr in boys and 7.0 cm/yr in girls. The mean PHV was less than 1 cm in boys and girls of about 17 years and 15 years, respectively, with mean heights of 170.8 cm and 158.7 cm, respectively.

Conclusions. Our preliminary results were actually calculated from the combination of longitudinal data and cross-sectional data pools. Since this is only a pilot study design, we expect that a longer follow-up period of the same cohorts would give more exact growth characteristics.

The purpose of our study is to investigate the growth characteristics of groups of school boys and girls living in the Shih-Pai district of metropolitan Taipei. The focus of the study was to follow these boys and girls throughout their pubertal years so that a longitudinal growth curve could be obtained.

METHODS

From 1994 to 1997, a defined group of 1,139 healthy school children (570 boys and 569 girls) from the Shih-Pai district of Taipei were followed longitudinally for 4 years. They are school children recruited from 2nd to 4th grade at Shih-Pai Elementary School, 1st year of Shih-Pai Junior High School, and 1st year of

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Chung-Cheng Senior High School. For each grade, there were more than 200 children with equal ratio of male to female. The entire group, 313 boys and 308 girls, were followed in the 4th year. Anthropometric measurement of height and weight and physical development of each child were obtained by the same trained person. Six monthly measurements of weight and height were done. The midpoint of the 12-month interval during which the maximum yearly height and weight increment occurred was taken as age at peak height velocity (PHV) and age at peak weight velocity (PWV), respectively. Height velocity curve (HVC) and weight velocity curve (WVC) were plotted by calculation of the height and weight data at the 6-month interval.

Statistical analysis

Data are presented as mean \pm standard deviation (SD). Descriptive statistics and percentiles were estimated us-

ing flexible mathematical functions.

RESULTS

The results of the anthropometric measurement of height, height velocity, weight, and weight velocity in the different age groups of school children are listed in Tables 1 and 2. The age at PHV was taken as 12.5 years for boys and 10.5 years for girls, and the whole year velocity at PHV was taken as 8.0 cm/yr for boys and 7.0 cm/yr for girls. The mean height velocity was less than 1 cm in boys and girls of about 17 years and 15 years, respectively, with mean values of height of 170.8 cm and 158.7 cm, respectively. These percentile (50th centile) curves, for boys and girls of average height and average velocity, are illustrated in Fig. 1. The resulting curves are illustrated in Figs. 2 through 5; the suggested standards for "height and weight at-

Table 1. The 50th percentile values for height and whole-year height velocity for boys and girls

Age (years)	Boys		Girls	
	Height (cm)	Height velocity (cm/yr)	Height (cm)	Height velocity (cm/yr)
8	127.6		128.2	
9	133.1	5.5	134.8	6.6
10	137.3	4.2	139.5	4.7
11	144.6	7.3	146.5	7.0
12	150.6	6.0	152.3	5.8
13	158.6	8.0	155.0	3.3
14	165.8	7.2	157.0	2.0
15	169.4	3.6	157.7	0.7
16	170.5	1.1	158.7	1.0
17	170.8	0.3	159.3	0.6
18	171.1	0.3	159.5	0.2

Table 2. The 50th percentile values for weight and whole-year weight velocity for boys and girls

Age (years)	Boys		Girls	
	Weight (kg)	Weight velocity (kg/yr)	Weight (kg)	Weight velocity (kg/yr)
8	28.6		27.5	
9	31.4	2.8	30.8	3.3
10	34.9	3.5	34.8	4.0
11	39.4	4.5	40.0	5.2
12	43.8	4.4	43.7	3.7
13	47.8	4.0	46.7	3.0
14	56.8	9.0	51.2	4.5
15	61.8	5.0	54.1	2.9
16	63.4	1.6	53.1	-1
17	63.5	0.1	51.7	-1.4
18	65.6	2.1	52.1	0.4

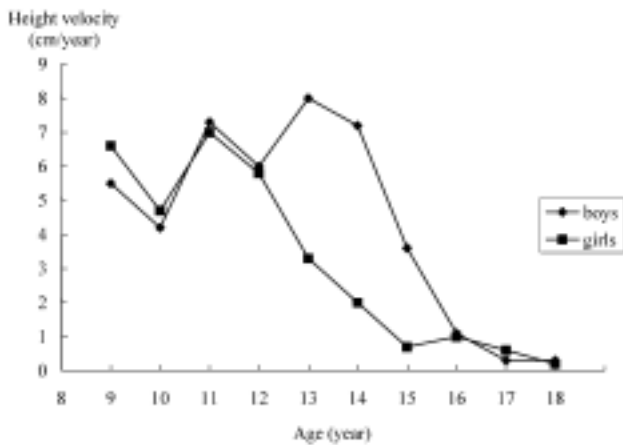


Fig. 1. 50th percentile of height velocity in boys and girls.

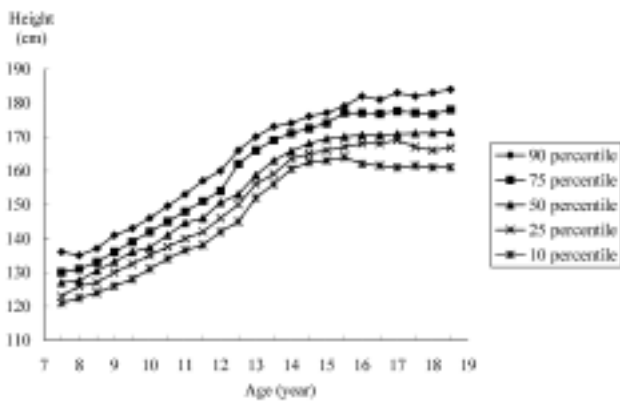


Fig. 2. Growth curve of height in boys.

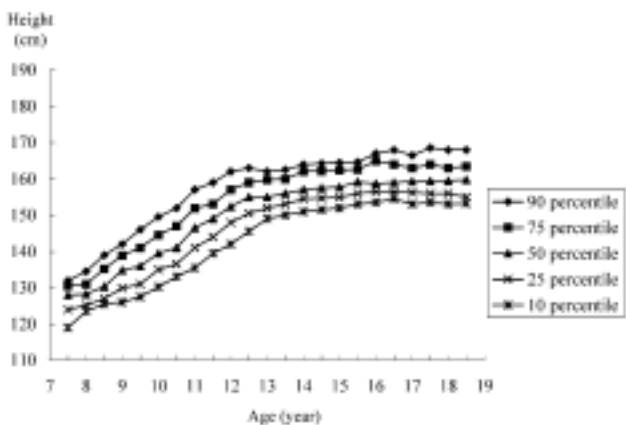


Fig. 3. Growth curve of height in girls.

tained” also give the 90th, 75th, 50th , 25th and 10th centiles for the cohorts of average values. These percentile (50th centile) curves, for boys and girls of aver-

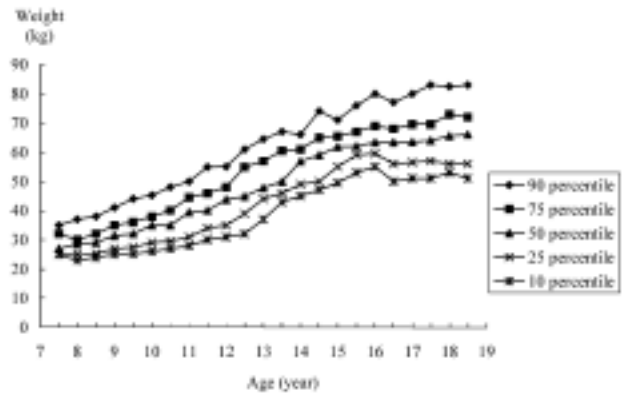


Fig. 4. Growth curve of weight in boys.

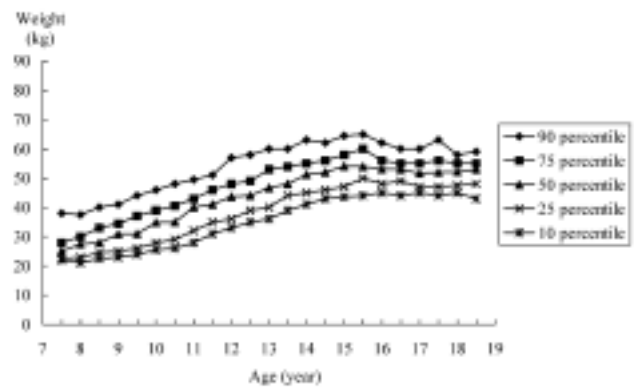


Fig. 5. Growth curve of weight in girls.

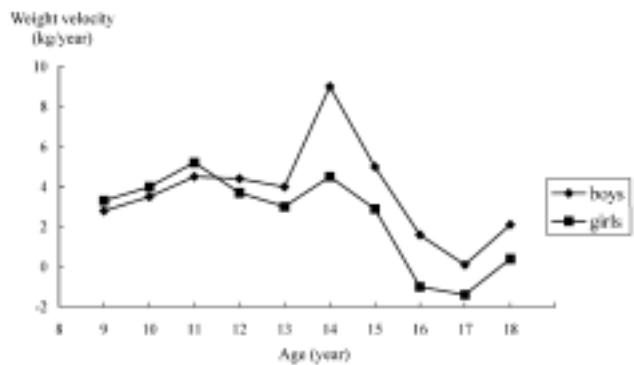


Fig. 6. 50th percentile of weight velocity in boys and girls.

age weight velocity, are illustrated in Fig. 6.

DISCUSSION

In this study, the mean age at peak height velocity was 12.5 years in boys and 10.5 years in girls, with

slight variations in the different studies. Marshall *et al.*⁹ reported the mean of 14.0 years in boys while Tanner *et al.*¹⁰ estimated it to be 13.9 years, with whole year PHV of 8.8 cm/yr in boys in the Harpendeen Growth Study. Billewicz *et al.*¹¹ observed that PHV for boys and girls were 9.63 cm/yr and 8.02 cm/yr, respectively. Largo *et al.*¹² reported an averages of 12 years for PHV in girls and of 14 years in boys based on a Zurich longitudinal study, and the whole year PHV was 7 cm and 9 cm in girls and boys, respectively. Tanaka *et al.*¹³ calculated linear growth in 438 boys and 483 girls aged from 6 years to 17 years in Japan. They reported a mean age of PHV to be 11.2 years in girls and 13.0 years in boys. The mean PHV was 8.7 cm/yr in girls and 10.3 cm/yr in boys. Abbassi¹⁴ reviewed the growth characteristics of

American boys and girls from published studies. Age at the onset of growth acceleration is highly variable and sex-dependent. The mean take off age in children growing at an average rate is 11 years in boys and 9 years in girls, and in these children, peak height velocities occur at a mean age of 13.5 years and 11.5 years, respectively. Whole year peak height velocity is 9.5 cm/yr in boys and 8.3 cm/yr in girls, with slight variations in the different studies. In US cross-sectional studies, boys with a mean takeoff age of 11 years reached their final heights by 17 years of age, and girls with a mean takeoff age of 9 years reached their final heights by 14 years of age. Comparisons of 50th percentile values for height in school children in different reports in Taiwan are shown in Table 3.^{1,4,15}

Table 3. Comparison of 50th percentile values for height in school children in different reports in Taiwan

Age (yr)	Boys (cm)				Girls (cm)			
	1971-72 ¹⁵	1980-82 ¹	1986-88 ⁴	present study	1971-72 ¹⁵	1980-82 ¹	1986-88 ⁴	Present study
8	122.3	123.5	125.7	127.6	121.6	123.2	124.6	128.2
9	126.9	129.4	130.5	133.1	127.0	129.1	130.2	134.8
10	132.9	134.3	135.3	137.3	132.3	135.3	136.0	139.5
11	136.9	140.3	140.5	144.6	138.9	142.2	142.5	146.5
12	141.8	144.7	146.6	150.6	145.1	146.7	148.0	152.3
13	149.6	152.8	153.6	158.6	150.1	151.3	152.5	155.0
14	156.2	159.9	159.8	165.8	152.8	154.6	154.7	157.0
15	161.8	163.6	164.1	169.4	154.9	155.4	156.4	157.7
16	166.6	164.7	168.5	170.5	155.6	155.1	158.1	158.7
17	167.6	166.0	169.9	170.8	156.4	156.0	158.9	159.3
18	167.5	169.0	170.1	171.1	156.2	155.0	158.8	159.5

Table 4. Comparison of 50th percentile values for weight in school children in different reports in Taiwan

Age (yr)	Boys (kg)				Girls (kg)			
	1971-72 ¹⁵	1980-82 ¹	1986-88 ⁴	present study	1971-72 ¹⁵	1980-82 ¹	1986-88 ⁴	present study
8	22.0	23.0	24.8	28.6	21.4	22.7	23.5	27.5
9	23.9	25.7	27.1	31.4	23.6	25.8	26.1	30.8
10	26.1	28.7	30.2	34.9	26.4	28.9	29.8	34.8
11	28.6	32.4	33.4	39.4	29.9	33.0	34.2	40.0
12	31.0	35.7	37.9	43.8	34.6	36.7	38.2	43.7
13	37.1	41.3	43.1	47.8	38.8	41.5	42.7	46.7
14	42.3	47.3	48.6	56.8	41.9	45.1	45.0	51.2
15	47.5	51.4	52.2	61.8	46.0	46.8	47.9	54.1
16	53.8	52.7	56.3	63.4	47.8	48.0	48.4	53.1
17	55.2	55.9	57.9	63.5	48.9	49.2	48.9	51.7
18	56.4	58.4	59.7	65.6	49.0	49.3	49.5	52.1

If we apply Tanner's¹⁰ definition of adult size as "an increase of less than 1 cm in height or 0.5 cm in other measurements over a period of at least 1 year", the boys and girls in this study reached adult size at about 17 years and 15 years, respectively.

Conventional charts give an erroneous impression of the course of growth in adolescence if we follow a single child longitudinally, as in most clinical work. This is due to the 'phase-difference' effect,⁷ which is also listed and illustrated in this study. The dynamics of pubertal growth are best represented by height-velocity charts rather than by standard charts. Longitudinal, rather than cross-sectional, growth data are necessary for constructing height-velocity charts. It is similar in this study.

The clinical use of these growth-velocity charts requires calculating the child's growth velocity and knowing his or her pubertal status. The six-month increments have a consistently higher variability than the annual increments.⁷ A satisfactory assessment of a child's growth cannot be made over a period of less than 1 year.¹⁶ Body weight has been evaluated and compared in different times in Taiwan (Table 4), and was found to increase dramatically in the past few decades.^{1,4,15} In this study, we calculated the annual increments every 6 months. As 4 years of follow up periods are relatively short compared with 6 to ten years usually spent,^{5-8,10-12} our preliminary results were actually calculated from the combination of longitudinal data and cross-sectional data pools. Since this is only a pilot study design, we expect that longer follow-up periods of the same cohorts would give more exact growth characteristics.

In conclusion, the present study on child growth at puberty found that the age at takeoff is highly variable and gender-dependent, occurring at a mean age of 12.5 years for boys and 10.5 years for girls. PHV is 8 cm/yr in boys and 7 cm/yr in girls.

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