ORIGINAL ARTICLE

A Longitudinal Study of Growth Patterns in Schoolchildren in One Taipei District II: Sitting Height, Arm Span, Body Mass Index and Skinfold Thickness

Tian-Shing Lee[1], Ting Chao[1], Ren-Bin Tang[1,3]*, Chia-Chang Hsieh[1], Shu-Jen Chen[1,3], Low-Tone Ho[2,3]

Departments of [1]Pediatrics and [2]Medical Research and Education, Taipei Veterans General Hospital, and [3]National Yang-Ming University School of Medicine, Taipei, Taiwan, R.O.C.

Background: It has been suggested that longitudinal rather than cross-sectional growth standards be used to assess individual growth patterns. Thus, the aim of this study was to follow boys and girls throughout their pubertal years, so that a mixed longitudinal growth curve of height, weight, sitting height, arm span, skinfold thickness, body mass index (BMI), and the ratio of sitting height or arm span to stature, could be obtained.

Methods: A defined group of 1,139 healthy schoolchildren (570 boys and 569 girls) from the Shih-Pai district of Taipei were followed longitudinally for 4 years. Anthropometric measurements of height, weight, sitting height, arm span, skinfold thickness, and BMI, were obtained for each child.

Results: Peak sitting-height velocities of 6.1 cm/year (boys) and 6.3 cm/year (girls) were seen at 8.5 years. The second peak of sitting-height velocity occurred at a mean age of 12.5 years for boys and 11.5 years for girls. Sitting-height velocity for the whole year covering the second peak was 4.6 cm in boys and 3.2 cm in girls. Peak arm-span velocity was seen at 13.5 years for boys and 8.5 years for girls, and arm-span velocity for the whole year covering this peak was 8.4 cm/year for boys and 8.1 cm/year for girls.

Conclusion: These data provide growth patterns for Chinese children aged 8–18 years living in a Taipei district, with percentile charts for sitting height, arm span, BMI, and skinfold thickness. [*J Chin Med Assoc* 2005;68(1): 16–20]

Key Words: arm span, body mass index, growth patterns, sitting height, skinfold thickness

Introduction

The accurate assessment of physical growth and development in children has attracted much attention from health care providers and pediatricians. Many studies report growth standards for height, weight, and triceps skinfold thickness for children in Taiwan.[1–4] However, such studies are based on cross-sectional surveys, and differ from standards for individual longitudinal growth. It has been argued that longitudinal, rather than cross-sectional, growth standards should be used to assess individual linear growth. Indeed, differences are particularly marked in standards for growth velocity.[5–8]

Height and weight are the most common parameters used for assessing growth patterns. Besides standing height, growth rates in different parts of the body can be determined from sitting height, arm span, and the ratio of sitting height or arm span to stature. Such growth charts are useful for evaluating disproportional growth retardation. Hence, this study was designed to follow boys and girls, from one district of Taipei, throughout their pubertal years, and to obtain longitudinal growth curves for sitting height, arm span, skinfold thickness, body mass index (BMI), and the ratio of sitting height or arm span to stature.

*Correspondence to: Dr. Ren-Bin Tang, Department of Pediatrics, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.
E-mail: rbtang@vghtpe.gov.tw • Received: December 30, 2003 • Accepted: August 31, 2004

Methods

Between 1994 and 1997, 1,139 healthy schoolchildren (570 boys and 569 girls) aged 8–18 years and from the Shih-Pai district of Taipei were followed longitudinally for 3–4 years. The children were divided into 5 groups: groups 1–3 were recruited from the 2nd to 4th grades of Shih-Pai Elementary School; group 4 from the 1st grade of Shih-Pai Junior High School; and group 5 from the 1st grade of Chung-Cheng Senior High School. Each group comprised more than 200 children, and contained an equal proportion of males and females.

Due to yearly graduation, the entire study population finally comprised only 313 boys and 308 girls. Anthropometric measurements of sitting height, arm span, and subcutaneous fat for standard skinfold measurements of the biceps and triceps (Lange skinfold caliper), were obtained by the same trained technician. The midpoint of the 12-month interval during which the maximum yearly sitting-height and arm-span increment occurred was recorded as the age at peak sitting-height velocity and peak arm-span velocity, respectively.

Sitting height, leg length, and arm span were plotted by calculation of data at 6-monthly intervals. Sitting height was measured using the sitting-height table, with the subject sitting with their back straight, head in the sagittal plane, and upper surface of the thighs horizontal and feet supported so that a right angle was formed between the thighs and the backs of the calves. Leg length was measured, using a standing-height meter, from the plantar surface of the feet to the superior external border of the left greater trochanter. Arm span is the longest distance from the tip of the third digit on the left hand to the tip of the third digit on the right hand and, thus, includes shoulder width, and the length of both arms and hands; each child stood erect facing a wall, to which a tape ruler was attached in a plane parallel to the floor, but at the child's shoulder level.

Statistical data are presented as mean ± standard deviation (SD). Descriptive statistics and percentiles were estimated using flexible mathematic functions.

Results

Tables 1 and 2 list measurements of sitting height, arm span, and triceps and biceps skinfold thickness, for the different age groups of schoolchildren. The peak sitting-height velocity of 6.1 cm/year was seen at age 8.5 years for boys, and that of 6.3 cm/year was seen at age 8.5 years for girls. The second peak of sitting-height velocity occurred at a mean age of 12.5 years for boys and 11.5 years for girls. The sitting-height velocity for the whole year in which the second peak occurred was 4.6 cm in boys and 3.2 cm in girls (Table 3). Values for peak arm-span velocity of 8.4 cm/year in boys and 8.1 cm/year in girls were seen at age 13.5 years and 8.5 years, respectively (Table 4).

Percentile curves of sitting height, arm span, and leg length, for girls and boys are shown in Figures 1–6. The suggested attained standards also give the 90th, 75th, 50th, 25th and 10th percentiles of average values for the cohorts. Sitting height and arm span were good predictors of height. The mean ratio of sitting height to leg length was relatively constant, and changed linearly from 1.06 to 1.18 in boys, and from 1.06 to 1.21 in girls. The mean ratio of arm span to height

Table 1. Mean (± standard deviation) values for sitting height, leg length, arm span, sitting height/height, sitting height/leg length, arm span/height, triceps skinfold thickness, biceps skinfold thickness, body mass index and weight/height for boys

Age (yr)	Sitting height (cm)	Leg length (cm)	Arm span (cm)	Sitting height/ height	Sitting height/ leg length	Arm span/ height	Triceps skinfold thickness (mm)	Biceps skinfold thickness (mm)	Body mass index (kg/m^2)	Weight/ height (kg/cm)
8	65.5 ± 3.5	61.8 ± 2.8	127.1 ± 5.4	0.51 ± 0.02	1.06 ± 0.06	1.00 ± 0.02	11.9 ± 4.9	6.8 ± 3.1	17.5 ± 0.3	0.23 ± 0.04
9	71.6 ± 3.3	61.5 ± 3.0	133.9 ± 6.1	0.54 ± 0.01	1.16 ± 0.06	0.98 ± 0.17	13.1 ± 5.6	6.8 ± 3.7	17.8 ± 1.9	0.24 ± 0.04
10	74.0 ± 3.3	63.2 ± 3.4	138.7 ± 6.5	0.54 ± 0.01	1.17 ± 0.06	1.01 ± 0.02	14.1 ± 6.9	7.0 ± 4.2	18.4 ± 3.3	0.25 ± 0.05
11	76.8 ± 3.8	67.8 ± 4.7	146.8 ± 8.7	0.53 ± 0.01	1.14 ± 0.06	1.02 ± 0.02	15.0 ± 7.7	7.5 ± 4.4	18.7 ± 3.3	0.27 ± 0.05
12	79.3 ± 3.8	70.9 ± 4.2	152.8 ± 8.4	0.53 ± 0.01	1.12 ± 0.06	1.02 ± 0.02	14.3 ± 8.1	7.1 ± 4.8	19.3 ± 4.0	0.29 ± 0.07
13	83.9 ± 4.0	74.8 ± 4.0	160.3 ± 9.0	0.53 ± 0.01	1.12 ± 0.05	1.00 ± 0.10	12.1 ± 5.5	7.3 ± 3.1	18.9 ± 3.1	0.33 ± 0.06
14	87.6 ± 3.9	77.6 ± 4.7	168.7 ± 7.8	0.53 ± 0.01	1.13 ± 0.06	1.02 ± 0.25	11.3 ± 6.0	5.5 ± 3.3	20.6 ± 3.3	0.34 ± 0.06
15	90.4 ± 3.2	78.2 ± 3.9	172.2 ± 13.1	0.53 ± 0.01	1.16 ± 0.06	1.02 ± 0.02	10.8 ± 5.4	5.6 ± 3.0	21.5 ± 3.3	0.37 ± 0.06
16	91.7 ± 3.3	78.8 ± 4.8	173.3 ± 6.1	0.54 ± 0.01	1.16 ± 0.06	1.01 ± 0.10	9.2 ± 5.5	5.7 ± 2.8	21.8 ± 3.2	0.38 ± 0.06
17	92.3 ± 3.2	79.0 ± 3.6	175.0 ± 7.8	0.54 ± 0.09	1.17 ± 0.06	1.03 ± 1.03	10.0 ± 4.6	4.6 ± 2.6	21.8 ± 4.1	0.37 ± 0.07
18	93.2 ± 3.3	79.3 ± 4.8	175.5 ± 7.7	0.55 ± 0.01	1.18 ± 0.06	1.03 ± 0.02	11.3 ± 4.8	5.7 ± 3.0	22.3 ± 2.9	0.38 ± 0.05

varied from 0.98 to 1.03 in boys, and from 0.99 to 1.03 in girls, and the mean ratio of sitting height to height was also relatively constant (0.51–0.55 in both boys and girls).

Values for BMI increased from 17.5 kg/m^2 (8 years) to 22.3 kg/m^2 (18 years) in boys, and from 16.6 kg/m^2 (8 years) to 20.5 kg/m^2 (18 years) in girls. Triceps and biceps skinfold thicknesses are shown in

Table 2. Mean (± standard deviation) values for sitting height, leg length, arm span, sitting height/height, sitting height/leg length, arm span/height, triceps skinfold thickness, biceps skinfold thickness, body mass index and weight/height for girls

Age (yr)	Sitting height (cm)	Leg length (cm)	Arm span (cm)	Sitting height/ height	Sitting height/ leg length	Arm span/ height	Triceps skinfold thickness (mm)	Biceps skinfold thickness (mm)	Body mass index (kg/m^2)	Weight/ height (kg/cm)
8	65.7 ± 2.9	62.4 ± 2.9	126.9 ± 5.9	0.51 ± 0.01	1.06 ± 0.05	0.99 ± 0.02	12.7 ± 4.9	6.6 ± 2.8	16.6 ± 3.1	0.27 ± 0.04
9	72.0 ± 3.1	62.9 ± 3.2	135.0 ± 6.7	0.53 ± 0.01	1.15 ± 0.05	1.00 ± 0.02	13.6 ± 5.6	7.1 ± 3.7	16.9 ± 2.9	0.23 ± 0.04
10	75.1 ± 3.6	64.9 ± 3.7	140.2 ± 7.6	0.54 ± 0.01	1.16 ± 0.06	1.00 ± 0.02	14.8 ± 6.1	7.3 ± 3.7	17.7 ± 3.3	0.25 ± 0.05
11	77.8 ± 4.3	68.1 ± 4.5	146.6 ± 8.3	0.53 ± 0.01	1.15 ± 0.06	1.01 ± 0.02	14.4 ± 6.2	7.3 ± 3.9	18.7 ± 3.4	0.27 ± 0.05
12	81.0 ± 3.8	71.2 ± 3.8	154.1 ± 7.0	0.53 ± 0.01	1.14 ± 0.05	1.01 ± 0.02	13.5 ± 5.2	6.3 ± 2.7	18.7 ± 2.9	0.29 ± 0.05
13	82.7 ± 7.9	71.1 ± 6.4	157.0 ± 6.8	0.54 ± 0.01	1.16 ± 0.07	1.03 ± 0.13	14.5 ± 5.3	7.5 ± 2.5	19.4 ± 3.3	0.32 ± 0.06
14	85.3 ± 3.2	71.6 ± 3.2	158.8 ± 6.1	0.54 ± 0.01	1.19 ± 0.06	1.01 ± 0.02	17.3 ± 6.1	7.9 ± 3.5	20.8 ± 3.3	0.33 ± 0.05
15	85.5 ± 3.0	71.7 ± 3.3	158.9 ± 6.3	0.54 ± 0.01	1.19 ± 0.06	1.01 ± 0.02	17.4 ± 6.2	9.2 ± 4.5	21.7 ± 3.7	0.34 ± 0.06
16	86.8 ± 3.2	71.9 ± 3.4	159.6 ± 6.2	0.55 ± 0.01	1.14 ± 0.13	1.01 ± 0.10	17.0 ± 6.0	8.2 ± 3.2	21.1 ± 2.5	0.32 ± 0.04
17	87.2 ± 2.9	72.2 ± 3.2	160.5 ± 5.8	0.55 ± 0.01	1.21 ± 0.07	1.01 ± 0.02	16.0 ± 5.6	6.8 ± 2.5	20.3 ± 2.3	0.32 ± 0.04
18	87.7 ± 2.8	72.3 ± 3.4	160.6 ± 6.0	0.55 ± 0.01	1.21 ± 0.06	1.01 ± 0.02	16.3 ± 5.2	6.9 ± 2.5	20.5 ± 2.0	0.33 ± 0.03

Table 3. Mean (± standard deviation) values for sitting height and whole-year sitting-height velocity for boys and girls

Age (yr)	Boys		Girls	
	Sitting height (cm)	Sitting-height velocity (cm/yr)	Sitting height (cm)	Sitting-height velocity (cm/yr)
8	65.5 ± 3.5		65.7 ± 2.9	
9	71.6 ± 3.3	6.1	72.0 ± 3.1	6.3
10	74.0 ± 3.3	2.4	75.1 ± 3.6	3.1
11	76.8 ± 3.8	2.8	77.8 ± 4.3	2.7
12	79.3 ± 3.8	2.5	81.0 ± 3.8	3.2
13	83.9 ± 4.0	4.6	82.7 ± 7.9	1.7
14	87.6 ± 3.9	3.7	85.3 ± 3.2	2.6
15	90.4 ± 3.2	2.8	85.5 ± 3.0	0.2
16	91.7 ± 3.3	1.3	86.8 ± 3.2	1.3
17	92.3 ± 3.2	0.6	87.2 ± 2.9	0.4
18	93.2 ± 3.3	0.9	87.7 ± 2.8	0.5

Table 4. Mean (± standard deviation) values for arm span and whole-year arm-span velocity for boys and girls

Age (yr)	Boys		Girls	
	Arm span (cm)	Arm-span velocity (cm/yr)	Arm span (cm)	Arm-span velocity (cm/yr)
8	127.1 ± 5.4		126.9 ± 5.9	
9	133.9 ± 6.1	6.8	135.0 ± 6.7	8.1
10	138.7 ± 6.5	4.8	140.2 ± 7.6	5.2
11	146.8 ± 8.7	8.1	146.6 ± 8.3	6.4
12	152.8 ± 8.4	6.0	154.1 ± 7.0	7.5
13	160.3 ± 9.0	7.5	157.0 ± 6.8	2.9
14	168.7 ± 7.8	8.4	158.8 ± 6.1	1.8
15	172.2 ± 13.1	3.5	158.9 ± 6.3	0.1
16	173.3 ± 6.1	1.1	159.6 ± 6.2	0.7
17	175.0 ± 7.8	1.7	160.5 ± 5.8	0.9
18	175.5 ± 7.7	0.5	160.6 ± 6.0	0.1

Tables 1 and 2; increases with age for boys were smaller than corresponding increases for girls.

Discussion

In this study, mean ratios of sitting height to leg length were 1.06–1.18 for boys and 1.06–1.21 for girls. Another study of Chinese children showed this ratio to change gradually in boys, from a mean of 1.4 at age 4 years, to 1.14 at age 16 years; in girls, the ratio changed from 1.36 at age 4 years, to 1.14 at age 12 years, and to 1.18 at age 16 years.[9] Similar growth patterns were observed in other studies, but actual ratios differed according to race.[6,7,10–16] The ratio of sitting height to leg length in our study was greater than that documented for Caucasians and Africans, e.g. 0.85–0.95 in American blacks compared with 1.06–1.21 in our study; indicating that the ratio varies among ethnic groups.[9,11,14–16]

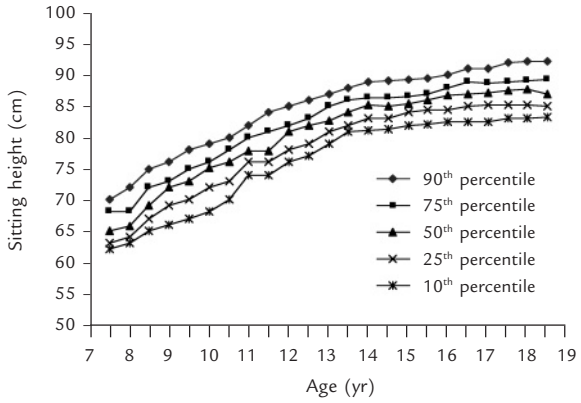

Figure 1. Percentile distribution of sitting height in girls.

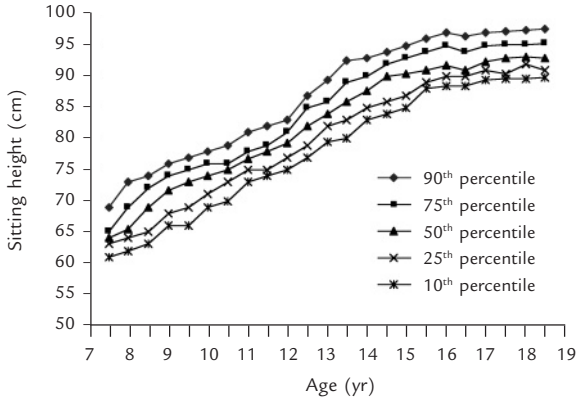

Figure 2. Percentile distribution of sitting height in boys.

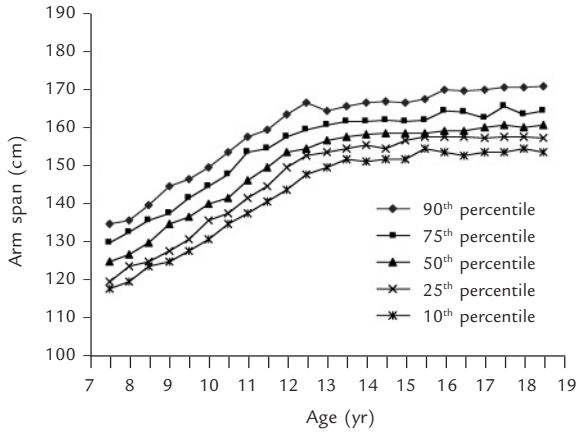

Figure 3. Percentile distribution of arm span in girls.

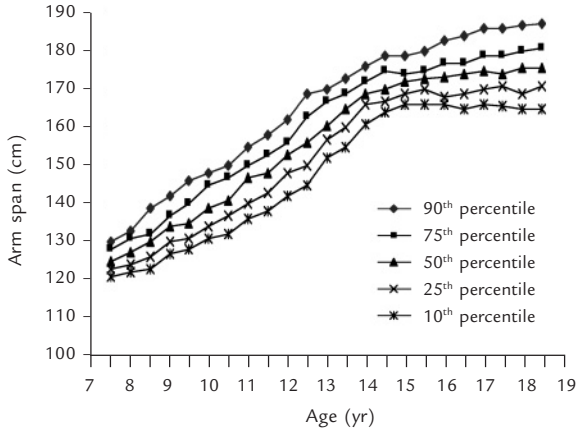

Figure 4. Percentile distribution of arm span in boys.

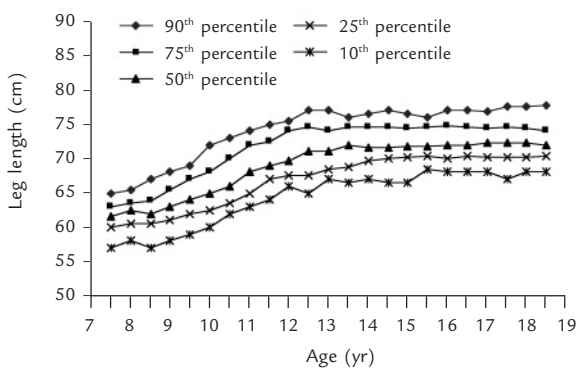

Figure 5. Percentile distribution of leg length in girls.

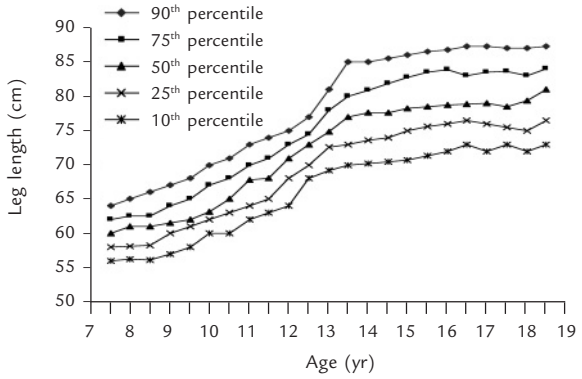

Figure 6. Percentile distribution of leg length in boys.

Reeves et al[17] indicated that the ratio of arm span to height was significantly different in Afro-Caribbean and Asian males, and Jarzem and Gledhill[18] recently reported that height can be reliably predicted from arm-span measurements. The relationship between arm span and height can be useful in other clinical contexts, such as when height cannot be measured properly because of disability or deformity. Steele and Mattox[15] reported that, on average, the arm span for black women was 8.3 cm greater than height, whereas the arm span for white women was only 1.8 cm greater than height. Thus, the relationship between arm span and height varies between ethnic groups.[17] In the present study in Chinese children, arm-span to height ratio had a relatively constant mean of 0.98–1.03 in boys and 0.99–1.03 in girls. Our study also suggests that arm-span measurements may be a useful predictor of height in Chinese children, since a close association was found between arm span, and arm-span to height ratio.

Casey et al[19] demonstrated that body fat distribution (its continuity from childhood to 30 years of age, and its link to that in parents) could be described in a longitudinal study population. In the present study, BMI values increased from 17.5 kg/m^2 (8 years) to 22.3 kg/m^2 (18 years) in boys, and from 16.6 kg/m^2 (8 years) to 20.5 kg/m^2 (18 years) in girls. Weight-to-height index gives an insensitive indication of obesity, especially in children, because it includes contributions from bone, muscle, and body water. Using biceps and triceps skinfold measurements and upper arm circumference, areas of fat and lean tissue at the arm can be determined approximately based on cylindrical assumption. During puberty, decreased skinfold thickness may be due to a real loss of fat tissue.[20,21]

In conclusion, our data define growth patterns for children aged 8–18 years in a district of Taipei, with percentile charts for sitting height, arm span, BMI, and skinfold thickness, in both boys and girls.

Acknowledgments

This study was supported by grants from the Taipei Veterans General Hospital, Taiwan, and the Department of Health, Taiwan.

References

1. Lin YM, Chu CL, Hong CL, Huang PC. Assessment of nutritional status of the youth in Taiwan, I: body height and body weight. *J Chin Nutr Soc* 1985;10:91–105.
2. Lai ES, Yaung CL. Growth curves of adolescent students in Changhua city, Taiwan. *J Formos Med Assoc* 1988;87:633–40.
3. Hsiao RL, Miau TS, Lu CC, Tsai CC, Lin MT, Wu CC, Lin MH, et al. A survey on weight and height of children (1 month–7 years) and plotting of growth curves (1 month–18 years) in Taiwan, 1987–1988. *Acta Paediatr Sin* 1990;31:166–75.
4. Kao MD, Huang HI, Tzeng MS, Lee NY, Shieh MJ. The nutritional status in Taiwan – Anthropometric measurement 1986–88 (II) triceps skinfold and mid-arm circumference. *J Chin Nutr* Soc 1991;16:87–100.
5. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. *Arch Dis Child* 1976;51:170–9.
6. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. Part I. *Arch Dis Child* 1966;41:454–71.
7. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. Part II. *Arch Dis Child* 1966;41:613–35.
8. Tanner JM, Davie PSW. Clinical longitudinal standards for height and height velocity for North American children. *Pediatrics* 1985;107:317–29.
9. Cheng JC, Leung SS, Lau J. Anthropometric measurements and body portions among Chinese children. *Clin Orthop* 1993;323:22–30.
10. Shephard RJ, Rode A. Growth patterns of Canadian Inuit children. *Arctic Med Res* 1995;54:60–8.
11. Yun DJ, Yun DK, Chang YY, Lim SW, Lee MK, Kim SY. Correlations among height, leg length and arm span in growing Korean children. *Ann Hum Biol* 1995;22:443–58.
12. Luo ZC, Low LCK, Karlberg J. Fetal size to final height in Hong Kong Chinese children. *J Pediatr Endocrinol Metab* 2000;13:269–79.
13. Han TS, Lean ME. Lower leg length as an index of stature in adults. *Int J Obes Relat Metab Disord* 1996;20:21–7.
14. Steele MF, Chenier TC. Arm span, height, and age in black and white women. *Ann Hum Biol* 1990;17:533–41.
15. Steele MF, Mattox JW. Correlation of arm-span and height in young women of two races. *Ann Hum Biol* 1987;14:445–7.
16. Leung SS, Lau JT, Xu YY, Tse LY, Huen YF, Wong GW, Law WY, et al. Secular changes in standing height, sitting height and sexual maturation of Chinese — the Hong Kong growth study, 1993. *Ann Hum Biol* 1996;23:297–306.
17. Reeves SL, Varakamin C, Henry CJ. The relationship between arm-span measurement and height with special reference to gender and ethnicity. *Eur J Clin Nutr* 1996;50:398–400.
18. Jarzem PF, Gledhill RB. Predicting height from arm measurements. *J Pediatr Orthop* 1993;13:761–5.
19. Casey VA, Dwyer JT, Berkey CS, Baily SM, Coleman KA, Valadian I. The distribution of body fat from childhood to adulthood in a longitudinal study population. *Ann Hum Biol* 1994;21:39–55.
20. Gasser T, Ziegler P, Largo RH, Molinaari L, Prader A. A longitudinal study of lean and fat areas at the arm. *Ann Hum Biol* 1994;21:303–14.
21. Barker M, Robinson S, Osmond C, Barker DJP. Birth weight and body fat distribution in adolescent girls. *Arch Dis Child* 1997;77:381–3.