Medical Hypotheses (2002) **59**(6), 759–761

doi:10.1016/S0306-9877(02)00326-2, available online at http://www.idealibrary.com

Pubertal height gain: male–female and interpopulation comparisons

Richard P. Spencer

University of Connecticut Health Center, Farmington, Connecticut, USA

Summary Data are not available as to the exact age of the start of the pubertal growth spurt (or age at its conclusion) in various populations. As an initial approach, contribution of the pubertal gain to overall height was examined, using age 9 as the start of puberty in girls and age 11 in boys. Data were analyzed from 11 reports (single assays on five populations, two studies on a group analyzed 30 years apart, and four studies of a population spread over 31 years. Using the percent contribution to overall height, pubertal growth showed a close agreement between the populations as well as between male and female values (overall $p < 0.003$). Results for both sexes clustered around a narrow range. Pubertal growth for the 50th percentile, expressed as a percent contribution to overall height, may approach a biologic invariant. The value of percent contribution of pubertal growth to final height, did not show a secular trend.

INTRODUCTION

While growth occus throughout childhood, the 'pubertal growth spurt' makes a significant contribution, as the young adult then emerges. This phase of growth has been mentioned in both medical literature and the lay press because of marked food consumption and changes in body proportions. An examination was therefore made of one aspect of this, namely the pubertal height gain.

Three questions were asked.

1. In various populations, what percent of overall height was gained during this period?
2. Was there a close relationship between the percent height gain in males and females of each population?
3. Did the percent height gain during this growth spurt change over the past 40 years (secular trend)?

Received 8 May 2002

Correspondence to: **Richard P. Spencer** MD, PhD, Division of Nuclear Medicine, Diagnostic Imaging and Therapeutics, University of Connecticut Health Center, Farmington, CT 06030-2804, USA. Tel.: +1-860-679-4022; Fax: +1-860-679-2164;
E-mail: rspencer@adp.uchc.edu

ANALYSIS

It is apparent that data are needed as to when the pubertal growth spurt begins in each population and when this has ended. Definitive values are not available for each group. Using the height increment after age 9 in girls and age 11 in boys does not necessarily mean that the pubertal period has been included. It does represent a comparison between defined ages, with the known human sex difference of pubertal onset of about 2 years. However, the assay can be extended when more specific values emerge for the onset and conclusion of the pubertal growth spurt in each population.

MATERIALS AND METHODS

Data were collected from references listed in the NIH Pubmed, under the heading of 'pubertal growth spurt.' Only utilized were reports that listed standing height data. For girls this required values from age 9 to 18 years (or beyond), while for boys results had to be present from age 11 through 18 years or beyond. Employed was the mean value for normals, or that for the 50th percentile. Statistical analyses were performed by the Microsoft excel program.

An initial concern was that a secular growth change, with the passing years, might obscure pubertal contributions to overall height. To address this, an analysis was carried out as described below. An example of the trend to increasing height in recent years can be seen in data for Portugese males (age 20) who presented for military service (1). Letting 1960 be year 1, values had been reported for 5 year intervals up to 1990 (year 31). The regression equation for height (*H* in cm) as a function of the year (*Y*) was:

$$H = 167 + 0.2Y. \quad [1]$$

The p value was less than 0.0001. Additionally, secular growth in the Netherlands (1955–1997) has been observed (2). Another example of changing values can be noted on the stature of girls in Jena, Germany (3). However this covered only a limited number of ages. If we express the results as the height gain from ages 9 to 14 years, as a percent of the height at age 14, a time varying result (increasing) became apparent. Hence, in subsequent analyses, the year of the assay was listed (when it had been described).

RESULTS

Presented in Table 1 is a side by side comparison of standing height for boys and girls, for several populations. Noted was the approximate time (year) in which the data were gathered. Calculated was the contribution of height gain (starting at puberty) to final height. For girls, age 9 was used as the onset of puberty, while age 11 was employed for boys.

The percent contribution of pubertal growth spurt to total height in boys (*B*) was expressed as a function of the same measurement in girls (*G*). The relationship, for the 11 populations, was:

$$B = 0.88G + 2.1. \quad [2]$$

The p value was < 0.003.

Because of concern over possible secular changes, an analysis was carried out of results of the first population series (1951–1982) and the group of later studies (1988–2000). The values are shown in Table 2. There was no difference in the percentage contribution of the pubertal spurt to overall height between the earlier and later series (and no difference between boys and girls).

Table 1 reveals a close coupling of values of the percent pubertal contribution to overall height between boys and girls in each population. Bourguignon commented on 'Variations in duration of pubertal growth...' as a mechanism for minimizing the effects of differences in the timing of puberty (11).

Karlberg constructed a model of human growth which consisted of 3 components referred to as infancy, childhood and puberty (16). He noted in this model '...the Puberty component is shown to be time invariant.'

From data in Table 1, if we define ultimate height of the boy or girl as *U*, and the height at the start of puberty as *H*, then the following relationship is suggested.

$$(U - H)/U = \text{constant} \quad [3]$$

or alternatively:

Table 2 Value of the contribution of the pubertal growth spurt (mean and standard deviation), as percent of total height, for six reported series from 1951 to 1982, and five series from 1988 to 2000

	Percent contribution	
	Boys	Girls
1951–1982	18.6 ± 1.03	18.9 ± 0.97
1988–2000	18.4 ± 0.80	18.6 ± 0.67

Table 1 Contributon of pubertal growth to final height

Reference	Group		Percent contribution	
			Boys	Girls
(4)	1988	US, white, 50th height percentile	18.6	19.0
(5)	1996	Chinese, 1993	19.3	19.6
		Chinese, 1993	17.3	17.9
(2)	2000	Netherlands, 1996–97	19.5	19.4
(6)	1966	Britain, 1965	20.2	19.5
(7)	1995	Croatia, 1951	18.7	20.0
		1964	18.0	18.8
		1973	17.5	17.5
		1982	17.8	18.1
(8)	1988	Switzerland, urban Long*	18.6	18.8
(9)	1996	Italy	18.1	17.9
		Mean	18.5	18.8
		S.D.	0.89	0.82
		$p = < 0.003$		
Long*: longitudinal study				
	Using measurement at 'take off'			
(10)	1976	Britain	15.9	15.5

Age 9 years was used as the start of the pubertal spurt in girls and age 11 in boys.

$$1 - (H/U) = \text{constant.} \quad [4]$$

Biologic invariants have been discussed in terms of phylogenetic classifications (12,13). Charnov has presented a more general discussion of invariants in biology (14). However, ultimate validity of this concept for the value of the pubertal growth spurt contribution awaits data as to the precise onset and conclusion of the growth.

The analysis presented here was based on the mean value of height in a population, or the 50th percentile. It would be of interest to extend this to other percentiles of male and female height, to determine if there is still coupling between values for the sexes. The assumption of onset of puberty at age 9 in girls and age 11 in boys, used in the present analysis, should be tested on data from earlier population studies (if available). An attempt was made to analyze male/female data on other age cohorts, without a constant result.

Ohsawa and associates studied a group of Chinese girls (15). They tabulated data on those who had not menstruated up to age 18 years, and compared height data with girls who had menarche at age 9 and above. There were few cases at the upper extreme (older girls who had never menstruated) and also few at the lower extreme (early age of menarche). Analyzing the contribution to total height of values at age 9 and above, there was a marked difference between the two groups. A result of 17.5% was seen in those who had not menstruated as compared with 14.3% in girls who had menstruated. Likely the nonmenstruating group had a hormonal deficiency (perhaps estrogen), with failure to close the osseous growth plates at an appropriate age.

Another approach to determining the age at which to begin calculation of the pubertal growth spurt is to utilize the ''age at takeoff.'' That is, the age at minimum velocity of the growth curve. A value is shown for this from one study at the bottom of Table 1 (10). Further analysis might be extended to populations which have experienced disease or famine, to determine if there is an ''uncoupling'' of the otherwise closely related male/female values for the pubertal contribution to overall height.

REFERENCES

1. Gavao-Teles A., Camilo-Alves A. Secular trends of weight, height and obesity in cohorts of young Portugese males in the District of Lisbon: 1960–1990. *Eur J Epidemiol* 1998; **14**: 299–303.
2. Fredriks A. M., Van Buren S., Burgmeijer R. J. F., Meulmeester J. F., Beuker R. J., Brugman E., Roede M. J., Veerloove-Vanhorick S. P., Wit J. M. Continuing positive secular growth change in the Netherlands. *Pediat Res* 2000; **47**: 316–323.
3. Kromeyer-Hauschild K., Jaeger U. Growth studies in Jena, Germany: changes in body size and subcutaneous fat distribution between 1975 and 1995. *Am J Human Biol* 1998; **10**: 579–587.
4. Abbassi V. Growth and normal puberty. *Pediatrics* 1998; **102**: 507–511.
5. Leung S. S., Lau J. T. F., Xu Y. Y., Tse L. Y., Huen K. F., Wong G. W. K., Law W. Y., Yeung W. K. Y., Leung N. K. Secular changes in standing height, sitting height and sexual maturation of Chinese—the Hong Kong growth study, 1993. *Ann Human Biol* 1996; **23**: 297–306.
6. Tanner J. M., Whitehouse R. H., Takaishi M. Standards from birth to maturity for height, weight, height velocity and weight velocity: British children, 1965. *Arch Dis Childh* 1966; **41**: 613–635.
7. Prebeg Z., Jursea V., Kujundzic M. Secular growth changes in Zagreb school chidren over 4 decades, 1951–1991. *Ann Human Biol* 1995; **22**: 99–110.
8. Prader A., Largo R. H., Molinari L., Issler C. Physical growth of Swiss children from birth to 20 years of age. *Helv Paed Acta Supp* 1988; **52**: 3–125.
9. Zoppi G., Bressan F., Luciano A. Height and weight reference charts for children aged 2–18 years from Verona, Italy. *Eur J Clin Nutrit* 1996; **50**: 462–468.
10. Tanner J. M., Whitehouse R. H., Marubini E., Resele L. F. The adolescent growth sourt of boys and girls of the Harpenden growth study. *Ann Human Biol* 1976; **3**: 109–126.
11. Bourguignon J. P. Variations in duration of pubertal growth: a mechanism compensating for differences in timing of puberty and minimizing their effects on final height. *Acta Paediatr Scand Supp* 1988; **347**: 16–24.
12. Ferretti V., Sankoff D. Phylogenetic invariants for more general evolutionary models. *J Theor Biol* 1995; **173**: 147–162.
13. Fu Y. X., Li W. H. Necessary and sufficient conditions for the existence of certain quadratic invariants under a phylogenetic tree. *Math Biosci* 1991; **105**: 229–238.
14. Charnov E. L. In: *Life History Invariants.* Oxford: Oxford University Press, 1993: 167.
15. Ohsawa S., Jia C. Y., Kasai N. Age at menarche and comparison of the growth and performance of pre- and post-menarcheal girls in China. *Am J Human Biol* 1997; **9**: 205–212.
16. Karlberg J. A biologically-orientated mathematical model (ICP) for human growth. *Acta Pediat Scand Supp* 1989; **350**: 70–94.