

Height Velocity in Apparently Healthy North Indian School Children

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Abstract

Objective: Linear growth is best estimated by serial anthropometric data or height velocity (HV). In the absence of recent data on growth velocity, we undertook to establish normative data in apparently healthy North Indian children. **Materials and Methods:** Prospective longitudinal study in a representative sample of 7710 apparently healthy children, aged 3–17 years from different regions of Delhi. Height was measured at baseline and at 12 months while pubertal examination was performed at baseline in a subset of children. **Results:** The data on HV and puberty were available in 5635 participants (73.08%; 2341 boys and 3294 girls) and 1553 participants (622 boys; and 931 girls), respectively. The mean peak height velocity (PHV) was 7.82 ± 2.60 cm in boys seen at 12–12.9 years and 6.63 ± 1.81 cm in girls at 10–10.9 years. Although late maturing boys had a greater HV than early or normal maturers, it did not vary with the age of pubertal maturation in girls. HV correlated with parental height in prepubertal boys, girls, and pubertal boys ($P < 0.01$) while no correlation was seen in girls. **Conclusions:** The study presents normal height velocities in North Indian children. A secular trend was observed in achieving PHV in both boys and girls.

Keywords: Adolescent growth, anthropometry, growth spurt, growth velocity, puberty

INTRODUCTION

Linear growth (height) is a fundamental and discernible parameter of growth. The serial measurement of height, known as height velocity (HV), is a better indicator of growth than single point estimates. Documentation of abnormal HV is necessary in investigating any child with short stature. Due to inherent genetic variations and environmental influences, population specific reference charts are used to interpret growth. The HV charts are available for few countries.^[1-4] At present, the available growth charts for Indian children aged >5 years are based on cross-sectional data.^[5-7] There are few earlier Indian studies that have reported HV^[8-10] with limitations of small sample size, absence of pubertal assessment, and lack of data on recent trends. Therefore, we aimed to measure HV in apparently healthy school children in Delhi.

MATERIALS AND METHODS

The present study was carried out in seven fee-paying schools of Delhi, selected from five geographical zones (North, South,

East, West, and Central regions). All schools were coeducational except one which enrolled only girls. The selection of schools was based on the permission granted by the school managements. Detailed written protocol was provided to all parents through school administration requesting them to give written consent for their children to participate in the study. After obtaining written consent from the parents for physical and pubertal examination before enrollment, a brief pro forma related to study was sent home to be filled by parents which included recent and past medical history, date of birth of child, and height of both parents. The study was approved by the Institutional Ethical Committee of All India Institute of Medical Sciences, New Delhi.

Apparently healthy children, aged 3–17 years, were recruited for the study. Any child with known chronic systemic disorder

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or taking any treatment for >1 month in last 3 months was excluded from the study. Assent was taken from children aged ≥ 7 years of age before conducting examination.

METHODS

Anthropometry

The anthropometric evaluation was carried out at baseline and follow-up visit at 12 months with a window period of 1 week. All measurements were made by skilled staff with participants dressed in minimal light clothing and without footwear. Heights were measured to nearest 0.1 centimeter with portable Holtain's stadiometer (Holtain Inc., Crymych, Pembrokeshire, UK) with the child positioned in Frankfurt plane. Weights were measured to nearest 0.1 kg with the digital weighing machine at baseline and at 12 months. The measurements were taken twice, and the mean was recorded as final. The scale and stadiometer were calibrated using the standard weight and height, respectively. Uniformity of staff was maintained for all measurements. The maximum intraobserver and interobserver variation in measurement of heights was 1 cm. Mid-parental heights (MPH) were computed based on heights provided by the parents.^[11] The exact date of birth was noted from pro forma provided by parents and confirmed by school records.

Pubertal assessment

Pubertal stage assessment was carried out at the first visit, in a subset of participants for logistic reasons. It was planned to undertake pubertal examination in every fourth child starting from first roll number of the class section. It was carried out by trained professionals of same sex, ensuring complete privacy using Tanner's method.^[12,13] In boys, testicular volume (TV) was assessed by comparative palpation with the Praders Orchidometer to nearest milliliter. Based on TV, pubertal stages in boys were defined as – Stage I (prepubertal stage) included participants with TV <4 ml, Stage II (early pubertal stage) – TV >4 ml but <8 ml, Stage III (mid-pubertal stage) – TV >8 ml but <15 ml, and Stage IV (fully matured stage) – TV ≥ 15 ml. ATV of 4 ml or greater was defined as the onset of puberty.^[14,15] If there was discrepancy in TVs of both right and left sides, the larger one was taken for final volume. Puberty in girls was considered if thelarche was observed, i.e., sexual maturity rating Stage 2.

The boys at pubertal onset (TV ≥ 4 ml) and girls at thelarche were analyzed to compute the 50th, 3rd, and 97th, centile for the age of pubertal onset. These values were interpreted as median age of pubertal onset, early, and delayed puberty, respectively, in both genders. Children who achieved puberty earlier than the 3rd centile of age were labeled as early maturers and those who were delayed beyond the 97th centile were late maturers.

Statistical methods

Descriptive statistics such as mean, median, standard deviation, and range for baseline as well as outcome variables were used. This enabled identification of any outliers and the type of distribution (normal or otherwise). The median age and 95%

confidence interval [CI] for pubertal age were calculated by probit analysis by logistic regression model. SPSS software version 20 (IBM corporation, Armonk, NY) was used for statistical analysis.

RESULTS

A total of 7710 children (3492 boys and 4218 girls), aged 3.0–16.9 years were recruited at the first visit. The HV data at 12 months were available for 5635 children (73.08%; 2341 boys and 3294 girls). The main reasons for drop-out were moving out of school after passing 12th grade and absenteeism on the day of examination. The detailed pubertal status was available in 1553 participants (boys 622 boys; 931 girls).

Table 1 shows the mean HV for specific age intervals. The peak height velocity (PHV) in boys and girls was observed at 12–12.9 years and 10–10.9 years, respectively, and was significantly greater in boys than girls (7.82 ± 2.60 vs. 6.63 ± 1.81 cm/year; $P < 0.05$). The 50th centile HV in boys decreased progressively from 4 years to 9 years of age remained stationary for another year, followed by gradual increase to reach PHV at 12 years. It then gradually slowed down to <2 cm/year by the age of 16 years. Likewise, 50th centile of HV in girls reached 7.15 cm which gradually decreased to 5.8 cm at 8 years followed by a gradual decrease to reach PHV of 6.4 cm at 10 years. It then rapidly decreased to <2 cm/year by 14 years of age. Table 2a and b show the age-appropriate centiles for HV in boys and girls.

Figure 1 shows the diagrammatic distribution of HV with age. The boys showed a brief decline in HV before pubertal growth spurt. This nadir was less pronounced in girls and occurred earlier at 7–8 years. The HV in girls declined steadily after PHV to <2 cm/year by 14 years of age. In contrast, boys entered puberty 10 years and continued growing till the age

Table 1: Height velocity of boys and girls as per age-specific ranges

Age group	Boys		Girls	
	<i>n</i>	HV (mean \pm SD)	<i>n</i>	HV (mean \pm SD)
3-3.9	19	7.36 \pm 0.77	72	7.67 \pm 1.21
4-4.9	39	7.18 \pm 1.22	122	7.18 \pm 1.03
5-5.9	172	7.23 \pm 1.42	256	6.77 \pm 1.22
6-6.9	237	6.92 \pm 1.50	332	6.30 \pm 1.09
7-7.9	213	6.47 \pm 1.59	338	6.18 \pm 1.59
8-8.9	214	5.84 \pm 1.38	358	6.01 \pm 1.57
9-9.9	192	5.71 \pm 1.25	282	6.63 \pm 1.81
10-10.9	196	6.08 \pm 2.16	331	6.58 \pm 1.89
11-11.9	270	7.07 \pm 2.54	357	5.79 \pm 2.03
12-12.9	287	7.82 \pm 2.60	281	4.32 \pm 2.45
13-13.9	216	6.67 \pm 2.16	187	2.53 \pm 2.72
14-14.9	167	5.46 \pm 2.94	173	1.54 \pm 1.75
15-15.9	97	3.18 \pm 2.42	141	0.87 \pm 1.59
16-16.9	22	1.71 \pm 1.54	64	0.63 \pm 1.41

SD: Standard deviation, HV: Height velocity

of 16–17 years. Boys had longer duration of pubertal growth spurt than girls.

The pubertal status was evaluated in 1553 participants (622 boys; 931 girls). Table 3 shows the distribution of HV in boys and girls, according to pubertal staging. The maximum increase in height was noted in Stage 3 among boys and in Stage 1 and 2 among girls. Figure 2 shows distribution of HV across pubertal stages with statistically significant differences in HV across all three stages ($P \leq 0.001$).

The median age of puberty in boys was 11.58 years (95% CI: 11.4–11.7 years) and 3rd and 97th centiles were 9.35 years and 14.08 years, respectively. Likewise, the median age in girls, was 11.3 years (95% CI: 11.2–11.44) with 3rd and 97th centiles being 8.88 years and 13.75 years, respectively.

The HV of early, normal, and late maturers was compared separately for both genders [Table 4]. The boys maturing late had a greater HV than those who achieved puberty either early or within normal age while no such relationship was seen among girls. HV did not show any correlation with BMI in either gender (data not shown).

HV correlated significantly to MPH, father’s height but not with mother’s height in all prepubertal subjects ($P < 0.01$). HV significantly correlated with MPH and either parent’s height among pubertal boys ($P < 0.01$). The HV in pubertal girls and both postpubertal boys and girls did not show any significant correlation to MPH or either parents’ height.

DISCUSSION

The present study depicts HV centiles of apparently healthy children, aged 3–17 years, over 12 months period from seven schools located in Delhi. The PHV of girls was lesser and attained earlier than boys.

Measurement of height and plotting on growth chart is one of the basic steps in the evaluation of growth disorders. Placement of height point at one time provides information about status of linear growth at that time only without any information about

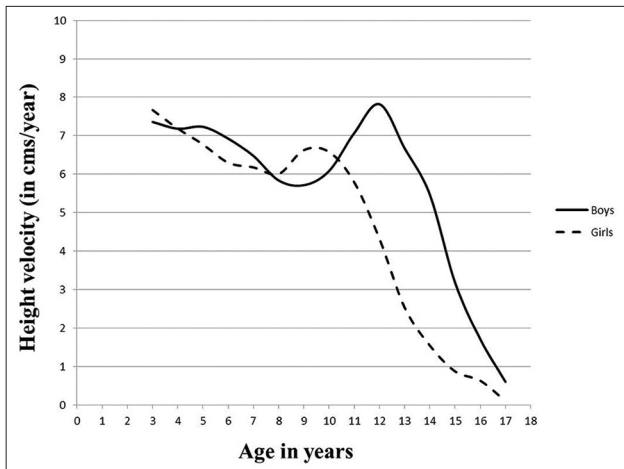


Figure 1: Age-wise mean annual height velocity of boys and girls

Table 2a: Height velocity centiles in boys

Age*	3 rd	10 th	25 th	50 th	75 th	90 th	97 th
4	3.64	5.79	6.4	7.2	8.2	8.5	9.26
5	4.84	5.69	6.30	7.19	7.97	8.80	11.22
6	4.81	5.30	6.0	6.70	7.75	8.82	9.77
7	4.39	4.90	5.60	6.30	7.10	8.46	9.89
8	3.59	4.70	5.20	5.80	6.5	7.10	8.86
9	3.87	4.60	5.0	5.5	6.20	6.97	8.17
10	4.0	4.39	4.89	5.5	6.5	8.42	13.12
11	3.80	4.39	5.0	6.45	8.52	10.89	13.29
12	3.90	4.59	5.89	7.60	9.39	11.5	13.03
13	2.65	3.89	5.20	6.40	8.20	9.52	10.79
14	1.09	1.80	3.30	5.10	7.69	9.09	10.7
15	0	0.54	1.09	2.89	4.45	6.56	8.51
16	0	0.32	0.60	1.30	2.12	5.11	5.30

*Age centiles for ages 3-3.9 years and 16-16.9 years not shown due to insufficient number of participants

Table 2b: Height velocity centiles in girls

Age*	3 rd	10 th	25 th	50 th	75 th	90 th	97 th
4	5.19	6.0	6.40	7.15	7.72	8.50	9.36
5	4.57	5.20	6.02	6.70	7.40	8.22	9.23
6	4.40	4.90	5.59	6.30	7.0	7.50	8.30
7	4.0	4.59	5.09	6.09	7.00	8.01	9.34
8	3.80	4.39	5.0	5.80	6.72	7.91	10
9	4.05	4.73	5.30	6.30	7.69	8.89	10.25
10	3.69	4.39	5.40	6.40	7.5	8.60	9.60
11	1.80	3.48	4.5	5.69	6.90	8.3	10
12	0.5	1.29	2.29	4.5	5.89	7.08	8.56
13	0	0.09	0.80	1.59	4.30	5.80	7.47
14	0	0	0.39	0.9	1.8	4.16	5.93
15	0	0	0	0.5	1.0	1.67	5.43
16	0	0	0.10	0.30	0.62	0.97	5.66

*Age centiles for ages 3-3.9 years and 16-16.9 years not shown due to insufficient number of participants

Table 3: Distribution of height velocity in boys and girls according to pubertal stages

Pubertal stage	Boys		Girls	
	n	HV (cm/year)	n	HV (cm/year)
Prepubertal/Stage 1	208	5.55±1.20	577	6.21±1.78
Stage 2	236	6.50±2.03	259	6.01±1.84
Stage 3	126	7.59±1.95	75	4.40±2.86
Stage 4 and 5	52	5.77±2.08	20	4.00±2.14

Data represented as mean±SD. SD: Standard deviation, HV: Height velocity

Table 4: Height velocity in relation to pubertal onset in boys and girls

Pubertal maturation	Median (95% CI)	
	HV in boys (cm/year)	HV in girls (cm/year)
Early	5.85 (4.25-10.69)	6.0 (5.23-7.71)
Normal	5.90 (5.70-6.2)	5.80 (5.60-6.0)
Late	7.8 (5.80-10.10)	6.0 (0.8-7.4)

HV: Height velocity, CI: Confidence interval

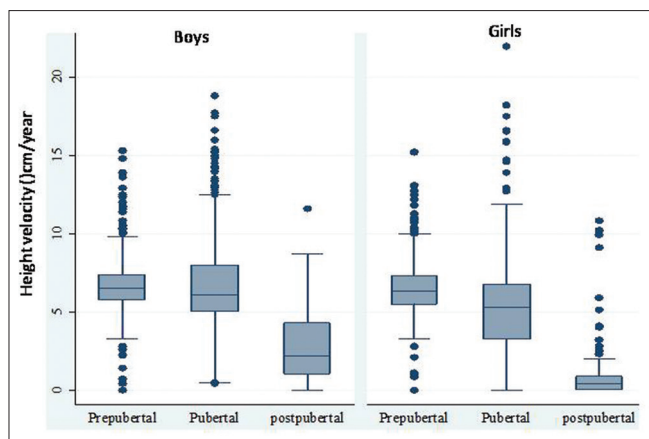


Figure 2: Distribution of height velocity in boys and girls with puberty

direction of growth. HV provides information about tempo of growth over a definitive time period and also been included in requirement for evaluation for growth disorders even in the absence of short stature (HV more than 2SD below the mean over 1 year).^[16] HV data and PHV data can also be used for prediction of final stature.^[17]

One of the earliest longitudinal studies of HV in Indian children was published in 1980^[9] where height of 303 boys and 260 girls from middle class families were reassessed at regular interval over a period of 14 years (1952–1966) PHV was reported at the age of 13.5 years in boys and 12 years in girls. Another longitudinal study on measurements of preschool children during an 18 year period of study (1965–66–1983–84) reported PHV at 14 years in boys.^[18] Similarly, study on girls from Northern India reported PHV at 11–13 years.^[19] In contrast, the attainment of PHV of boys at 12 years and girls at 10 years was earlier indicating a declining trend in age when compared to earlier reports in literature.^[9,10,18] This early attainment of PHV could well be due to early onset of puberty in Indian children as reported previously by us.^[20,21]

Similar secular trend in age of onset of puberty has also been reported from other countries.^[22]

Data from Taiwan reported PHV at 13 years in boys and 11 years in girls. Combined data from four US longitudinal studies of growth also reported PHV to occur at 12–13 years in boys and 10–11 years in girls.^[23]

Pubertal growth spurt is an important contributor to final stature. There exists ambiguity on whether pubertal timing affects HV. Hägg and Taranger reported greater final height in late maturing boys as compared to the early or normal maturers.^[24] However, others reported no statistically significant difference in final stature between subjects achieving early, normal or late onset of puberty maturation.^[1] Late maturing boys and girls were significantly taller than early maturers at pubertal onset; however, they were found to have smaller pubertal height gain, shorter pubertal duration and comparable final adult height.^[25] Similarly, Carrascosa *et al.* also reported greater pubertal height gain in early maturers than late maturers, but similar final adult

heights.^[26] In our study, HV did not vary with age of pubertal maturation in girls though late maturing boys had greater HV. However, the age of pubertal onset in our study may not be truly representative of true pubertal trends as pubertal assessment was carried out only at one point of time and in a subset.

A significant correlation between MPH/parent's height and HV was seen in prepubertal and pubertal boys and girls in our cohort. Su *et al.* had demonstrated a significant correlation between father's height to the tallest son's height and of mother's height to the shortest girl's height among Taiwanese adults, but HV was not evaluated.^[27]

The limitations of this study are (a) Lack of representation of children from low socioeconomic strata and rural areas. (b) Nonavailability of heights in these children at 6 months and longitudinal follow-up over few years would have been more representative of HV in Indian children. (c) Pubertal status was assessed only at the time of recruitment and in a subset of children. (d) Small number of participants in the age groups of 3–3.9 and 16–16.9 years of age.

CONCLUSIONS

The study reports HV of apparently healthy school children in the age group of 3–17 years from Northern India. The PHV showed a secular trend with boys achieving PHC at 12–12.9 years and girls at 10–10.9 years.

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Conflicts of interest

There are no conflicts of interest.

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