RESEARCH PAPER

Height Velocity Percentiles in Indian Children Aged 5-17 Years

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Objective: To assess height velocity and develop height velocity percentiles in 5-17-year-old Indian children; and to study the magnitude and age at peak height velocity.

Design: Mixed longitudinal study.

Setting: Private schools at Pune and Delhi.

Participants/patients: 2949 children (1681 boys) belonging to affluent class aged 5-17 years (1473-Pune, 1476-Delhi).

Methods*:* Annual height and weight measurements from 2007 to 2013. Total 13214 height velocity measurements (7724 on boys).

Outcome Measures: Height velocity percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) constructed using LMS chart maker.

Results: Age- and gender-specific height velocity percentiles were generated. Median height velocity in girls decreased from 5 to 8 years, increased to a peak of 6.6 cm at 10.5 years and then declined to 0.3 cm at 17.5 years. In boys, median height velocity reduced till 10.5, increased to a peak of 6.8 cms at 13.5 years and then declined to 1cm by 18 years.

Conclusions: Height velocity percentiles in 5-17-year-old urban Indian children were constructed**.**

Keywords: *Anthropometry, Growth, Peak height.*

Growth assessments are performed by cross-setional evaluation of child's height and weight on growth charts that are constructed on reference populations [1,2]. However, longitudinal rather than cross-sectional growth references are believed to be better representative of an individuals' growth pattern [3,4]. Thus, examining growth velocity may identify failure to thrive or response to a treatment early [4].

Pubertal growth spurt is the most rapid growth rate after infancy. Children differ in timing of onset and tempo of growth in puberty [5]. Hence, a mean of the growth velocities of individuals from a reference population does not represent the typical growth curve and peak velocity of pubertal growth [6]. This effect has been described as the phase difference. Tanner, *et al.* [6] shifted the separate height velocity curves to make their peak height velocities coincide when they constructed height velocity standards for the British population in 1966 [6]. Therefore, it is important to consider the phase difference and the timing of peak height velocity (PHV) to get a true picture of height velocities of the population being studied.

Longitudinal height velocity charts for North American, Korean and Swedish children have previously been published [7-9]. As childhood growth is affected by environmental and genetic factors, growth velocities of Indian children are likely to be different, particularly in pubertal years [10]. Thus, the aims of our study were (*i*) to assess height velocity and develop height velocity percentiles in 5-17-year-old apparently healthy Indian children from two centers from India *(*Pune and Delhi), and (*ii*) to study the magnitude and age at peak height velocity during adolescence in Indian children.

Accompanying Editorial: Pages 19-20

METHODS

This mixed longitudinal study was designed for assessing height velocity of Indian children aged 5-17 years and was conducted in Delhi (North) and Pune (West). Although this dataset was not part of Indian reference growth data, the studies were running parallelly; thus, methods of school and sample selection were similar [11]. Briefly, for school selection, nutritionally well-off areas (*i.e.* areas without slum clusters) in the city were identified and a list of schools catering to affluent children was made. Area was then selected randomly and three schools were selected as chosen by generating random numbers. The yearly fees of the selected schools were around Rs. 10000 (Indian per capita income 2007-2008, Rs. 2021/month) [11] when the study was initiated (2007).

All children from 5 till 17 years of age were annually measured from 2007 till 2013. As children left school, or as new children entered, children with a minimum of three readings (*i.e.* measurements for at least three years) were included in the study**.** Hence, in the first year, children were not measured after 15 years of age (***Table* I**). The study was approved by the Ethics Committee of the Hirabai Cowasji Jehangir Medical Research Institute, Pune. Permission and consent was obtained from school management and parents gave written consent for the use of de-identified data. Assents from children over 7 years were obtained. Date of births on all children were recorded from the school registers. Height was measured (Leicester Height Meter; Child Growth Foundation, London, range, 60-207 cm) using portable stadiometer and weight was measured using electronic scale (Salter, Faridabad, India); instruments were calibrated daily using standard height rod and weights. For height measurement, the child stood in socks on the flat base of the stadiometer with the back of the head, shoulder blades, buttocks and heels touching the vertical rod, and head in Frankfurt plane. Gentle traction was applied to the mandibular process and headboard lowered. The reading was taken to last completed mm and two readings were averaged for analysis. Throughout the study, same model and manufacture stadiometers were used at both the centers. Mean inter-observer and intra-observer coefficients of variation were <0.01 (1%) for height, indicating precision of measurements and that there were no significant differences among observers (P=0.34). Yearly measurements were repeated in all children between July to September by the same set of observers. Clinical assessments to rule out major illnesses were performed by pediatricians at both sites and children with any serious illness, or an illness likely to affect growth were measured, but were excluded from the study; data for these children were not entered or analyzed.

Baseline height and weight values (recorded in 2007) were analyzed by calculating Z-scores for height and weight using Centre for Disease Control charts and observations which were above and below +5 and -5 Z-scores were removed [12].

Annualized height velocity was calculated by using the formula: change in height in centimetres/change in time in years [13]. Individuals with data entry errors and

TABLE I BASELINE ANTHROPOMETRIC CHARACTERISTICS OF THE POPULATION

Age (years)	*n*	*Gender*	*Height (cm)*	*Weight (kg)*	*BMI (kg/m^2)*
5-6	85	M	110.8 (5.4)	18.2 (3.3)	14.8 (2.0)
	101	F	108.5 (5.6)	17.1 (2.7)	14.5 (1.6)
6-7	88	M	117.4 (5.8)	21.2 (3.7)	15.3 (1.7)
	124	F	116.8 (5.0)	20.1 (3.0)	14.7 (1.5)
7-8	128	M	123.4 (6.3)	24.6 (5.9)	16.0 (2.8)
	141	F	119.9 (6.2)	21.7 (4.3)	15.0 (2.0)
8-9	124	M	129.2 (5.1)	27.2 (6.8)	16.2 (3.4)
	146	F	124.8 (7.2)	24.2 (5.0)	15.4 (2.0)
9-10	253	M	133.5 (5.3)	30.7 (6.9)	17.1 (3.1)
	135	F	134.3 (5.5)	28.9 (5.9)	15.9 (2.5)
10-11	184	M	137.8 (6.1)	33.5 (7.5)	17.5 (3.1)
	151	F	142.0 (6.1)	35.4 (7.0)	17.5 (2.9)
11-12	137	M	143.8 (5.8)	38.5 (8.6)	18.5 (3.4)
	113	F	146.5 (6.6)	38.0 (8.2)	17.6 (3.3)
12-13	87	M	150.5 (7.5)	42.3 (8.6)	18.6 (3.0)
	92	F	151.7 (6.0)	41.5 (7.4)	18.0 (2.8)
13-14	45	M	154.9 (6.9)	45.9 (11.1)	19.0 (3.9)
	89	F	159.4 (6.1)	51.5 (9.9)	20.2 (3.5)
14-15	16	M	163.1 (7.7)	50.4 (10.2)	18.9 (3.2)
	20	F	155.2 (12.9)	49.6 (20.4)	20.1 (5.1)
15-16	18	M	169.4 (8.0)	63.3 (10.9)	22.1 (3.6)
	16	F	156.2 (8.9)	48.6 (14.4)	19.8 (4.8)

Data presented in mean (SD).

with less than three height readings were removed from analysis. Using these data, age and gender specific smoothed percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) for height velocity were constructed using the LMS method [14]. Each variable of interest was summarized by 3 smooth curves plotted against age representing the median (M), coefficient of variation (S), and skewness (L) of the measurement distribution [15]. Models were checked using detrended Q-Q plots, Q tests, and worm plots. LMS values were generated by the LMS method (LMS Chart Maker pro version 2.3); monthly height velocity values were generated; however, six monthly intervals have been presented here.

Peak velocity centered analysis: Girls and boys with PHV for two preceding and succeeding years around the peak were identified. Median and range of PHV's were calculated on the subset.

For a mixed longitudinal study with minimum of three time points and the group difference of 0.5 standard deviation units at each time point, necessary sample size was determined to be 47 per group for two group comparisons, assuming the attrition rate of 10% at each time point after the first, to be the same for all the groups, (r1 = 1, r2 = 0.9, r3 = 0.81), all pairwise correlations of the three repeated measures to be r= 0.5, and power to be 0.8 at 0.05 level of significance [16]. Further, for generating percentiles, 200 subjects per age-sex group is recommended [17]. Therefore, more children were enrolled per group. This resulted on post hoc power for present mixed longitudinal study with minimum of three-time points and the current sample size was adequate to suffice 0.9% power of the study with 5% level of significance.

RESULTS

A total of 13214 height velocity measurements on 2949

TABLE II BOYS HEIGHT VELOCITY PERCENTILES (IN CM)

Age years	*n*	*Percentile*						
		3rd	*10th*	*25th*	*50th*	*75th*	*90th*	*97th*
5	91	5.3	5.7	6.1	6.6	7.1	7.7	8.3
5.5		5.1	5.5	6.0	6.5	7.0	7.6	8.2
6	200	4.9	5.3	5.8	6.3	6.8	7.4	8.0
6.5		4.6	5.1	5.6	6.1	6.6	7.3	7.9
7	280	4.4	4.9	5.4	5.9	6.5	7.1	7.8
7.5		4.2	4.7	5.2	5.7	6.3	7.0	7.7
8	347	4.0	4.5	5.0	5.6	6.2	6.9	7.7
8.5		3.9	4.3	4.8	5.4	6.1	6.8	7.7
9	388	3.7	4.2	4.7	5.3	6.0	6.8	7.7
9.5		3.5	4.0	4.5	5.2	5.9	6.8	7.8
10	374	3.4	3.9	4.4	5.1	5.9	6.8	8.0
10.5		3.3	3.8	4.4	5.1	6.0	7.0	8.3
11	378	3.3	3.8	4.4	5.2	6.1	7.3	8.8
11.5		3.3	3.8	4.5	5.3	6.4	7.7	9.4
12	377	3.3	3.9	4.6	5.6	6.7	8.2	10.1
12.5		3.4	4.1	4.9	6.0	7.4	9.1	11.2
13	337	3.4	4.2	5.3	6.5	8.1	10.0	12.3
13.5		3.2	4.2	5.4	6.8	8.6	10.6	12.9
14	267	2.7	3.8	5.1	6.6	8.4	10.4	12.6
14.5		2.0	3.2	4.5	6.0	7.7	9.5	11.4
15	216	1.4	2.5	3.7	5.1	6.5	8.1	9.8
15.5		0.9	1.8	2.9	4.0	5.3	6.6	8.1
16	101	0.6	1.3	2.2	3.2	4.3	5.4	6.6
16.5		0.4	1.0	1.7	2.4	3.3	4.3	5.3
17	32	0.3	0.7	1.2	1.8	2.5	3.3	4.2
17.5		0.2	0.5	0.8	1.3	1.9	2.5	3.3

children (Pune -1473, Delhi - 1476) were available (7724 measurements on boys) from 5 to 17 years. Total 398 (298 boys) deviant observations were removed from analysis (***Web Fig*. 1**). ***Table* I** summarizes age and gender specific mean (SD) for height and weight in boys and girls at the beginning of the study. The mean height *Z*-scores in boys and girls (-0.2 (1.1), -0.4 (1.1), respectively) and weight *Z*-scores (-0.2 (1.1), -0.3 (1.1), respectively) at the time of first measurement were close to zero in comparison with Indian reference growth data [2].

Height velocity percentiles: ***Table* II** and **III** (***Figs*. 1** and **2**) illustrate the height velocity percentiles for boys and girls respectively. Height velocity for boys and girls was higher at 5 years. Median height velocity in girls decreased from 5 years to 8 years to peak at 10.5 years (6.6 cm) and then declined to 0.3 cm at 17.5 years. In boys, median height velocity reduced till 10.5 years, peaked at 13.5 years (6.8 cm) and then declined to 1 cm by 17 years.

Peak height velocity where a minimum of five longitudinal readings of height velocities were available in 346 girls and 330 boys. Peak height velocity of 10.3 cms was achieved at 13.4 years in boys and peak velocity of 9.7 cms was achieved at 10.8 years in girls.

DISCUSSION

Height velocity percentiles as per age for Indian children and adolescents from 5-17 years have been presented. The peak median height velocities were 6.6 cm at 10.5 years in girls and 6.8 cm at 13.5 years in boys. Velocities were higher in the peak height velocity (PHV) centered data.

The strength of the study is that annual height velocities are reported in a large sample over a seven year

TABLE III GIRLS HEIGHT VELOCITY PERCENTILES (IN CM)

Age years	*n*	*Percentile*						
		3rd	*10th*	*25th*	*50th*	*75th*	*90th*	*97th*
5	51	5.0	5.5	6.1	6.6	7.3	7.9	8.6
5.5		4.7	5.3	5.8	6.4	7.0	7.7	8.5
6	157	4.5	5.0	5.5	6.2	6.8	7.5	8.3
6.5		4.2	4.7	5.3	5.9	6.6	7.4	8.2
7	212	3.9	4.5	5.1	5.7	6.5	7.3	8.1
7.5		3.7	4.3	4.9	5.7	6.4	7.3	8.2
8	282	3.6	4.2	4.9	5.7	6.5	7.4	8.5
8.5		3.5	4.2	4.9	5.8	6.7	7.8	9.0
9	294	3.4	4.2	5.0	6.0	7.1	8.3	9.7
9.5		3.3	4.2	5.1	6.3	7.5	9.0	10.6
10	296	3.2	4.1	5.2	6.5	7.9	9.6	11.5
10.5		3.0	4.0	5.2	6.6	8.2	10.1	12.3
11	324	2.6	3.6	4.9	6.4	8.2	10.2	12.7
11.5		2.2	3.1	4.4	5.9	7.7	9.9	12.4
12	329	1.6	2.5	3.7	5.1	6.9	9.0	11.5
12.5		1.1	1.9	2.9	4.2	5.8	7.8	10.2
13	318	0.7	1.3	2.1	3.2	4.7	6.4	8.5
13.5		0.4	0.9	1.5	2.4	3.6	5.0	6.8
14	208	0.2	0.6	1.1	1.9	3.0	4.3	5.9
14.5		0.1	0.4	0.8	1.5	2.4	3.5	4.9
15	117	0.1	0.2	0.6	1.1	1.8	2.8	4.0
15.5		0.0	0.2	0.4	0.9	1.6	2.4	3.5
16	20	-	0.1	0.4	0.8	1.4	2.2	-
16.5		-	0.0	0.2	0.6	1.1	1.7	-
17	20	-	0.0	0.1	0.4	0.7	1.2	-
17.5		-	0.0	0.1	0.3	0.5	0.9	-

WHAT IS ALREADY KNOWN?

Growth measurements are based on ethnic specific distance charts as prepared from cross-sectional studies.

WHAT THIS STUDY ADDS?

Age- and gender-specific height velocity percentiles are presented for Indian children aged 5-17 years.

longitudinal period, which also eliminated seasonal differences in measurements. However, a complete serial follow-up of a cohort of children was incomplete as children entered and left the study. Children under 5 years were not included in this study. The extreme centiles (3rd and 97th) were not presented for age group beyond/6 year due to small sample size. Sexual maturity staging was not done to correlate with PHV. However, data suggest that majority of girls and boys achieve PHV by Tanner stage 3 and stage 4, respectively [18]; peak height velocity centered data is thus presented in a subset.

Previously published studies have reported data on height velocity of Indian children [19,20]; however, to the best of our knowledge, this is one of the few Indian studies to report height velocities over a 7-year period.

An individual whose height is under the 3rd percentile or two standard deviations below mean is considered as stunted [2]. However, for a height velocity chart, individuals whose height velocity is under the 25th percentile are required to be investigated [21]. Most healthy children tend to keep to the same percentile on distance charts unlike height velocity where they may not remain in the same centile position as they grow. Thus, the correlation of height gain in subsequent years is often lower than correlation of attained height [6]. Taken together, growth velocity must always be interpreted in conjunction with attained growth. Thus, for the appropriate investigation of a child with growth failure use of both the distance and velocity data is necessary.

As children achieve their peak height velocities at different ages, calculating height velocity based on chronological age reduces the impact of maximum peak achieved by children during years of puberty [6]. The peak and age at PHV in current study were similar to earlier reports [6,14,22,23]. Hauspie, *et al*. [22] reported earlier age at PHV, possibly due to secular trend [24]. Satyanarayana, *et al*. reported a higher PHV of 7.6 cm at 14 years in boys, differences could be due to small sample size, different study design and rural- urban differences [25]. Chinese girls [26] had an earlier peak (10 years) and boys from the US were taller [14]. Chinese boys had higher PHV at an earlier age; these differences emphasize the importance of ethnic specific data [26].

In conclusion, height velocity percentiles in Indian

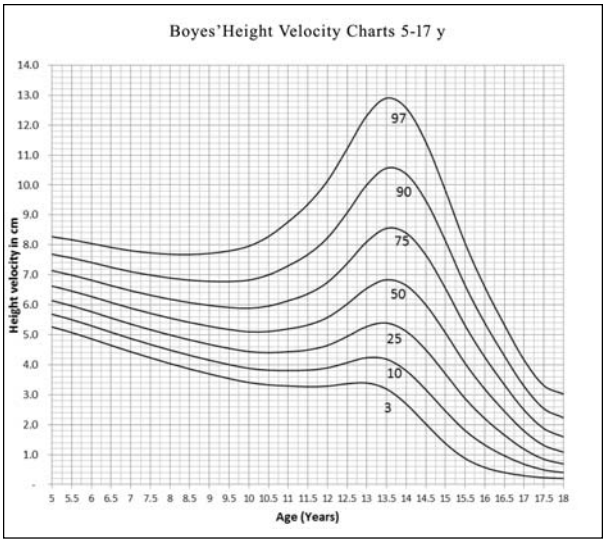

FIG. 1. *Height velocity charts for boys aged 5-17 years.*

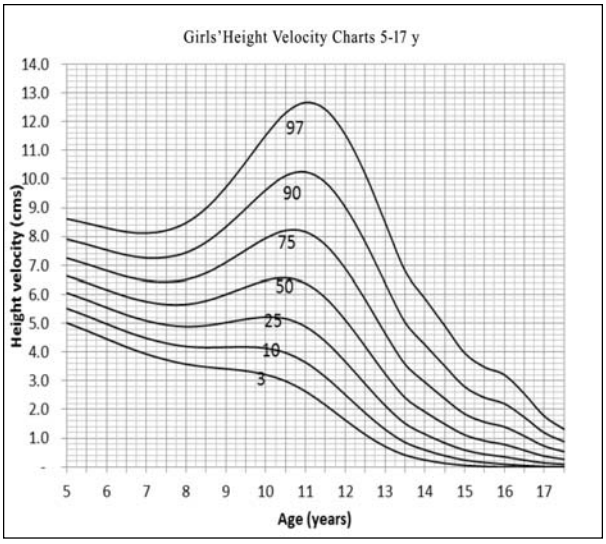

FIG. 2 *Height velocity charts for girls aged 5-17 years.*

children aged 5-17 years are presented. These data may be useful to assess growth velocities in Indian children.

Contributors: VK, AK, AA, ASC conceptualized the study and its design. AK, VE, NK, LP, SC, VP and SP contributed to data collection and analysis. All the authors provided critical inputs into manuscript writing, and approved its final version.
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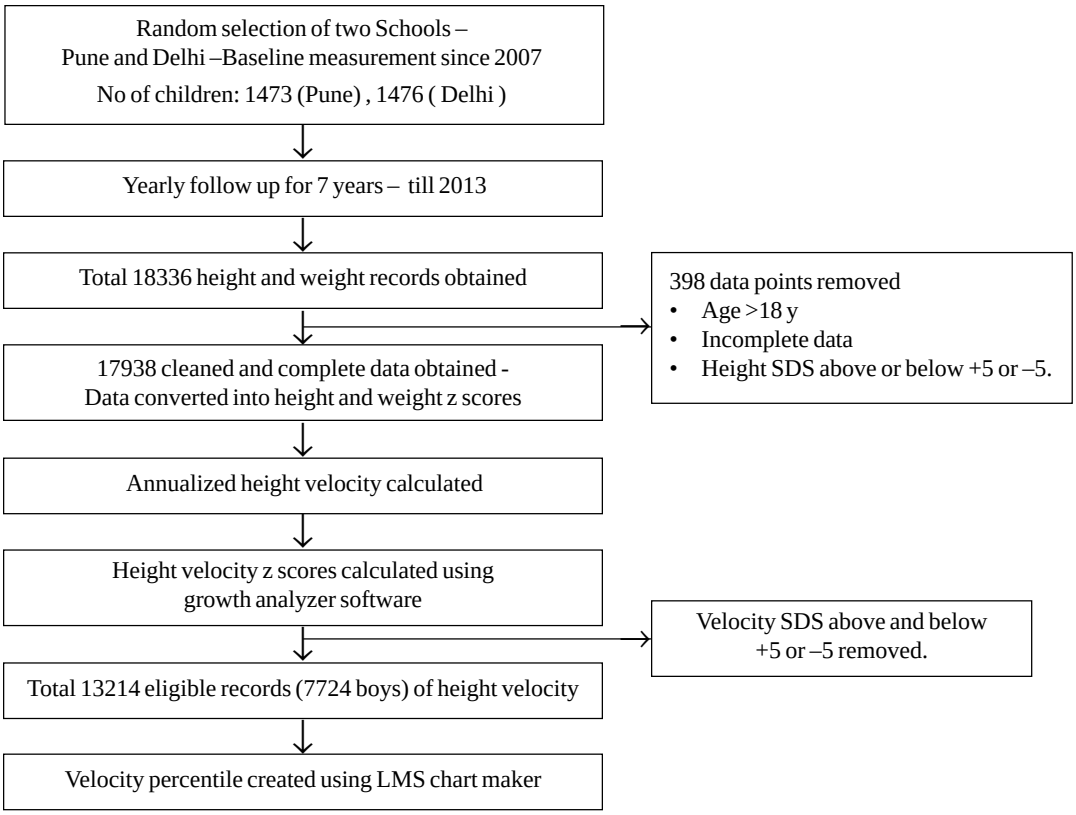

WEB FIG. 1 *Flow of children in the study.*