RESEARCH BRIEF

Foot Length As A Marker of Pubertal Onset

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This observational study was conducted on 973 healthy children between 8 and 16 years to evaluate the relation between changes in foot length and pubertal maturation. The right foot length of study children was recorded and SMR staging was done. The difference in mean foot length was statistically significant between SMR 1 and 2 (P<0.0001). No significant difference in the mean foot lengths was found thereafter. Smoothed standard deviation curves were constructed for foot length as a function of SMR stage using the LMS method. Foot length was found to rise sharply in SMR 2, which coincides with the onset of puberty.

Key words: *Foot length, India, Normogram, Puberty, SMR staging.*

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Adolescence is the period of rapid change in terms of physical and sexual development. More than 20% growth in stature and up to 40-50% of adult body weight is acquired during this period [1]. But there exists substantial individual variation in this physiological process. In this study we explored the relation of foot length change with pubertal onset and progress based on the physiological fact that these changes during adolescence are more strongly correlated with pubertal maturation than chronological age [2].

METHODS

This was a cross-sectional observational study correlating the foot lengths in males and females with their SMR stages.

Our target population was healthy children in the age group of 8-16 years, belonging to the middle income socio-economic status defined by the Wealth Index Scale [3]. Among the schools in Central Kolkata meeting our socio-economic status criteria, one boys' and one girls' school were randomly selected. Ethical clearance was obtained from the Institutional Ethics Committee of the study institution. The information regarding age was confirmed from the school register.

A pilot study was conducted with 20 boys and 20 girls in each age group over one month. On the basis of its results, assuming a significance level of 0.05 and a maximum consent refusal to be 50%, the estimated sample size with a power of 95% was a minimum of 90 for each age group. With 18 age groups, the estimated sample size was 1620. We approached 1641 healthy children in the age group of 8–16 years during the study period of 18 months (June 2008-November 2009). 41% of the subjects refused an SMR examination. 973 children (489 males) formed the final sample.

Age was recorded in decimal years. Right foot length measurement was taken one time using Brannock Foot Device. The subjects were made to stand barefoot with equal weight on both feet, placing their right heel in the heel cup. Foot length was recorded by looking straight down over the longest toe. Sexual development was assessed by inspection of pubic hair in both sexes along with examination of breast in girls, and penis and testes in

WHAT THIS STUDY ADDS?

- Change in foot length is one of the earliest and the most easily demonstrable physical growth change during puberty.

boys. Interpretation was based on Tanner's stages of sexual maturity [4]. Onset of puberty was defined as Tanner breast stage 2 or pubic hair stage 2 [5]. All parameters were evaluated by the same team of workers that comprised of five junior residents from the department. Inter-observer variations in assessment of SMR stages and measurement of foot length were assessed from a subset of the population using kappa statistics. Excellent inter-observer agreement was observed for all the parameters evaluated (kappa ratios being 0.79 for SMR staging, and 0.89 for foot length).

Data was analyzed using SPSS version 17.0. Student's *t* test was applied for analysis of all quantitative data sets. A *P* value less than 0.05 was considered to be significant. Reference standard deviation curves for foot length as functions of SMR stages were constructed using the LMS method of Cole and Green [7]. Growth Analyser 3.5 (build 197, Dutch Growth Foundation) was used for LMS curve fitting.

RESULTS

489 males and 484 females were analyzed during the study period. The number of children (boys, girls) in each age group was as follows: 8 years (55,52), 9 years (52,56), 10 years (55,57), 11 years (57,53), 12 years (54,60), 13 years (54,57), 14 years (53,50), 15 years (55,50) and 16 years (54,59). SMR staging was done in all the subjects and the data was rearranged and grouped according to their SMR stages in males and females.

The difference in mean foot length was statistically significant between SMR 1 and 2 in both sexes ($P<0.0001$). No significant differences in the mean foot lengths were found thereafter (***Table* I**). Smoothed standard deviation (SD) curves for foot length as a function of SMR stage in males and females are presented (***Fig* 1**).

DISCUSSION

The foot length in this study was found to rise sharply in SMR stage 2, which coincides with the onset of puberty [5]. Variation in foot lengths in the subsequent SMR stages was found to be insignificant.

Pubertal growth and physical development occur due to activation of the hypothalamic-pituitary-gonadal axis in late childhood. For both sexes,

TABLE I MEAN DIFFERENCE OF FOOT LENGTH (CM) WITH SMR STAGE IN BOTH SEXES

SMR stages	Male	Female
SMR 1		
Subjects (*n*)	252	173
Mean	17.41	17.79
SD	1.855	1.219
95% CI	17.18-17.64	17.61-17.98
SMR 2		
Subjects (*n*)	68	103
Mean	19.14	19.12
SD	1.058	0.719
95% CI	18.89 -19.4	18.98-9.26
SMR 3		
Subjects (*n*)	46	63
Mean	19.27	19.06
SD	0.880	0.759
95% CI	19.01-19.53	18.87-19.25
SMR 4		
Subjects (*n*)	80	83
Mean	19.3	19.18
SD	0.782	0.794
95% CI	19.14 -19.46	19-19.36
SMR 5		
Subjects (*n*)	45	60
Mean	19.46	19.45
SD	0.867	0.705
95% CI	19.18-19.75	19.27-19.63

Statistical difference between the foot length means of the SMR stages 1 and 2 was <0.0001 for both males and females, and >0.05 for all other stages; SD: Standard Deviation; CI: Confidence Interval.

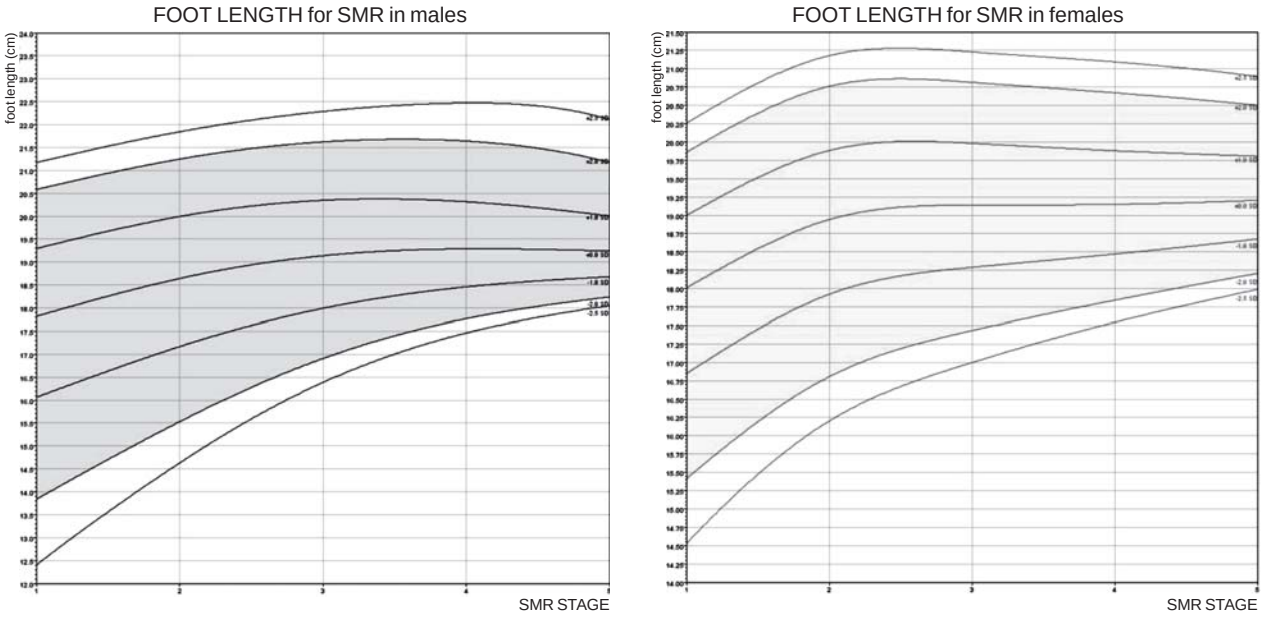

FIG.1 *SD curves showing foot length as a function of SMR stage in males and females* (*mean curve is bounded by ± 1, 2, 2.5 SD*).

growth acceleration begins in early adolescence, but peak growth velocities are not reached until SMR 3-4 [5]. It is well known that physical growth during puberty begins distally, with enlargement of the hands and feet, followed by the arms and legs and finally the trunk and chest [8]. We found foot length reached adult values at the onset of puberty. This observation is significant because it occurs before the start of pubertal height spurt. Hence it is one of the earliest, most easily demonstrable physical growth change during puberty.

It is often easier for the parents and children to recall a change in footwear rather than remembering the onset of breast development or appearance of pubic hair, hence providing a rough idea regarding the onset of puberty in clinical settings [2]. Foot length has previously also been shown to be an effective early marker of puberty [2]. Single one time foot length measurement cannot be used as a marker of pubertal onset. However, if taken serially in a pre-pubertal child, a sudden sharp rise in foot length may indicate onset of puberty.

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Contributors: SM planned and designed the study along with MS. MSa supervised the data collection. SM analysed the data and drafted the manuscript along with MSa. SC critically evaluated the manuscript.

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