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# Pediatric penile anthropometry nomogram: Establishing standardized reference values

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**Summary**
Anthropometry of the penis holds significant cultural and clinical importance, reflecting male genital development and aiding in the early identification of abnormalities.

**Objectives**
To develop an age-related penile length nomogram for Indian children, to define a range of normalcy, and to develop age-matched controls for penile length assessment in managing conditions like hypospadias.

**Methods**
This is a cross-sectional study (**Design**) initiated post-Institute Ethics Committee clearance (**Ethics**) based on 1276 volunteers (boys) aged 1—14 years (**Participants**) presenting to a pediatric surgery clinic (**Setting**) for conditions not affecting penile length. Participants were registered for the study and their age(years), weight(kg), and stretched penile length (SPL in cm) were recorded (**Intervention**). Generalized additive models for Location, Scale, and Shape (GAMLSS/extension of LMS method) were used. **Outcome measures included** weight (mean/range) and SPL (mean/range/standard deviation/median/centiles). The four distribution parameters were modeled as non-parametric smoothing cubic-spline functions of x with Box-Cox Power Exponential (BCPE) distribution and centiles (3, 5, 10, 25, 50, 75, 90, 95, 97) were calculated for the stretched penile length.

**Results**
SPL increases with age (3.4 cm in a 1-year-old to 12.7 cm in a 14-year-old) of the child in a non-linear fashion ($r = 0.67$, $p < 0.001$). Centile curves showed two phases of steep SPL increase, at ages 2—4 years and 10—14 years, reflecting early childhood growth and pubertal spurt respectively.

**Conclusions**
This is the largest cross-sectional study on the pediatric SPL in the Indian population. The data will serve as a useful resource for both parents and physicians in assessing penile development and guiding patient management.

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## Background and introduction

The penis has been regarded with significant cultural and symbolic importance throughout history [1]. The revered status is related to its role in sexual pleasure, reproductive potency, and an inseparable association with masculinity. Anthropometry of the penis is an important surrogate of male genital development and instrumental in the early identification of abnormalities. Time and again, pediatricians, pediatric surgeons and other specialists are confronted with parental concerns related to penile length or structure. Clinical conditions such as obesity, micro-penis, buried-penis [2], hypospadias [3], bladder exstrophy—epispadias complex [4], genetic aberrations or endocrine disruptions may be associated with sub-normal penile size [5,6]. Such conditions may have a significant impact on the child's health and psychosocial development. Sometimes, parental concerns related to false impressions gained from peer discussions or watching porn movies need to be mitigated through age-specific data guiding reassurance or further investigations.

Stretched penile length like other anthropometric variables is not universal and dependent upon origin or ethnicity and may exhibit a trend over successive generations. The studies available in literature are limited by small sample sizes and the robustness of statistical methodology. Given the clinical and psychological implications, the authors have undertaken to establish standardized references and generate centile curves based upon observations on a large and diverse cohort.

The current study seeks to develop age-related penile length nomogram for children, define the range of normalcy for penile length so that variations in penile biometrics may be better identified and addressed, and develop age-matched controls for penile length assessment which could be used as a yard-stick or reference model for managing patients with hypospadias and other related conditions.

## Material and methods

This is a cross-sectional study performed upon consecutive volunteers (boys) aged 1—14 years presenting to our clinic for unrelated conditions. Those with genital or other disorders known to affect the overall growth in general or the penile length such as malnutrition or other long-standing morbidities, hypospadias, cryptorchidism, disorders of sex differentiation, or other structural genital anomalies, and those who had multiple congenital anomalies, genetic or endocrine disorders were excluded.

The observation parameters for this study included age (years), weight (kilograms) and stretched penile length (centimeters). All measurements were taken in a weather-appropriate environment in the presence of either a parent or legal guardian. The observer wore fresh disposable gloves for each subject prior to recording the measurements.

**Weight** was recorded by a weighing machine. At the beginning of each measurement day, the accuracy of the scales was assessed with a known standardized weight. If the recording weight varied by more than 0.2 kg than the standard weight, the scale was re-calibrated and the procedure was repeated.

The child was asked to step-up and stand-still over the scale-center with body-weight evenly distributed between the feet. The child's arms were kept hanging freely by the sides of the body, with palms facing the thighs. The child was asked to hold his head up and face forward. Weight was recorded to the nearest 0.2 kg.

For smaller babies who couldn't stand unsupported, an electronic pan-type of infant/baby weighing scale was used with an accuracy of 5 gm, a minimum measuring capacity of 25 g, and a maximum weight of 20 kg.

Self-reported weights were not considered acceptable in this study.

The **penile length** was represented through Stretched Penile Length (SPL). SPL was measured in supine position by the Stretched Penile Length INdicator Technique (SPLINT) [7]. Prior to this study, the technique was validated by the lead investigator (PG) through assessment of intra-observer and inter-observer reliability [8]. The foreskin was retracted enough so that the meatus is the highest position with the patient supine and the penis held vertically. In neonates and older children with phimosis, it may not be possible to expose the meatus; in such situations, the tip of the glans is demarcated by placing a ruler horizontally against it with the help of manual palpation. Another ruler (graded in millimeters) was held vertical over the mons alongside the penis with one end compressing the pre-pubic subcutaneous fat at the base of the phallus. The penis was stretched fully while holding the penis at the corona between right thumb and index finger by the observer. The ruler was opposed along the side of the stretched phallus by the left hand of the observer. The distance from the lower end of the pubic bone to the tip of the glans (excluding the foreskin) was measured.

The measurements were done twice by the same observer (throughout the study) and the mean of the two measurements was recorded. The observer (persons taking the measurements) was different from the data-recorder (person entering the data). The observer would call out the value to the recorder. The recorder would call the number back to the observer to confirm the correct reading and make the entry.

### Statistical analysis

The data has been organized into age-based groups spanning from 1 to 2 years up to 13—14 years. Following standard conventions for class intervals, boys aged between 1 year or older but less than 2 years are categorized as 1 year of age, and those aged between 2 years or older but less than 3 years are categorized as 2 years of age, and so forth. The data is expressed as mean, standard deviation (SD), and range (minimum and maximum).

Data were entered and organized in an Excel spreadsheet (Microsoft Excel for Mac version 16.55). The data were analyzed after removing the outliers. Generalized additive models for Location, Scale, and Shape (GAMLSS) were used to fit the model [9-10] which is an extension of the LMS method [11]. Mean ($\mu$) and coefficient of variation ($\sigma$) were used to describe the location and scale parameters while the shape of the distribution was represented with skewness ($\upsilon$) and kurtosis ($\tau$). These parameters were modeled as non-parametric smoothing cubic spline functions of age with five effective degrees of freedom (edf) with Box—Cox Power Exponential (BCPE) distribution using Rigby and Stasinopoulos (RS) algorithm. Following model fitting, centile curves were generated for various age-groups, specifically depicting Stretched penile length at key percentiles: 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th.

Normalized quantile residuals were plotted to assess the model behavior while '*Worm plots*' were used to assess the goodness of fit at different regions of age. The calculated Q-statistics were used to test the normality of the residuals within a range of various age-intervals [12]. The GAMLSS model was fitted using the GAMLSS package of R version 4.4.1 and descriptive analysis was conducted using Stata (StataCorp LP, College Station, TX 77845, USA).

## Results

The cohort is comprised of 1276 consenting participants. Fourteen children were excluded from statistical analysis due to *outlier* measurements; the final analysis is based on 1262 subjects.

For each age-group, the sample size, mean (minimum-maximum) for weight and mean (SD, minimum, and maximum) for stretched penile length have been tabulated in Table 1.

The SPL increases with the age and weight of the subject. The smallest measured penis was 3.4 cm in a 1-year-old child, while the longest measured penis was 12.7 cm in a 14-year-old male. The relationship between age and SPL has been charted on a scatter plot (Fig. 1) revealing that as the age increases, SPL also increases [***correlation coefficient, r** = **0.67 (p** < **0.001)***]. Regression analysis indicated that for every one-year increase in age, SPL increased by an average of 0.25 cm.

$$\boldsymbol{Stretched}_{Penile_{Length(cm)}} = \mathbf{4.69} + \mathbf{0.25} * \boldsymbol{Age}(\boldsymbol{years})$$

The distribution parameter values (mean, coefficient of variation, skewness and kurtosis) and the percentiles (3, 5, 10, 25, 50, 75, 90, 95, 97) of stretched penile length (cm) by age (1—14 years) for children have been tabulated in Table 1. The SPL centile curves were characterized by a gradual increase with age; however, two phases of steep rise have been documented [Fig. 2]. The first phase comes in the age-group of 2—4 years. Subsequently, the penis undergoes a slow increase in SPL till the age of 8—10 years. The second phase of the steep rise is observed in the age-group of 10—14 years. This was the most notable rise in SPL due to the pubertal spurt in boys.

The normalized quantile residuals depicted an approximate normal distribution ($\mu$,: 0.003, $\sigma$: 1.001, $\upsilon$: −0.008 & $\tau$: 2.879) [Fig. 3A]. None of the six QQ Worm Plots depicted any model violation, suggesting no differences between theoretical model residuals and empirical mean, variance, skewness and kurtosis of residuals [Fig. 3B]. The Q statistics calculated for the model parameters were $Q_\mu = 3.15$ with df = 1.99, $Q_\sigma = 2.09$ with df = 5.0, $Q_\upsilon = 0.98$ with df = 1.99 and $Q_\tau = 3.93$ with df = 1.99 and none of them were statistically significant, indicating that the *edf* of five is adequate and the residuals are following a normal distribution.

**Table 1** Descriptive Statistics, Distribution Parameter Values and Percentiles of Stretched Penile Length by Age

| Age (years) | Sample Size (n) | Mean Weight (Range) | Mean | SD | Median | Min | Max | $\mu$ | $\sigma$ | $\upsilon$ | $\tau$ | 3rd | 5th | 10th | 25th | 50th | 75th | 90th | 95th | 97th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 80 | 8.43 (6–11.4) | 4.9 | 0.73 | 5.1 | 3.4 | 6.5 | 4.9 | 0.1 | 1.2 | 3.3 | 3.7 | 3.8 | 4 | 4.4 | 4.9 | 5.5 | 5.9 | 6.1 | 6.2 |
| 2 | 196 | 10.12 (6.8–13.7) | 5.2 | 0.7 | 5.2 | 3.4 | 6.7 | 5.2 | 0.1 | 1.4 | 2.8 | 3.8 | 3.9 | 4.2 | 4.7 | 5.2 | 5.7 | 6.1 | 6.3 | 6.4 |
| 3 | 166 | 12.43 (8–19.8) | 5.4 | 0.81 | 5.5 | 3.4 | 7.2 | 5.5 | 0.1 | 1.2 | 2.2 | 4 | 4.2 | 4.5 | 4.9 | 5.5 | 6 | 6.5 | 6.7 | 6.9 |
| 4 | 131 | 14.00 (10–27.4) | 5.9 | 0.79 | 5.9 | 4 | 8.4 | 5.8 | 0.1 | 0.9 | 1.9 | 4.4 | 4.5 | 4.8 | 5.3 | 5.8 | 6.4 | 6.9 | 7.2 | 7.4 |
| 5 | 104 | 15.73 (11.8–22.1) | 6 | 0.77 | 6 | 3.9 | 8.1 | 6.1 | 0.1 | 0.9 | 2 | 4.6 | 4.8 | 5 | 5.5 | 6.1 | 6.6 | 7.1 | 7.4 | 7.6 |
| 6 | 97 | 17.19 (10.2–26.2) | 6.3 | 0.89 | 6.3 | 3.9 | 8.6 | 6.3 | 0.1 | 0.9 | 2.2 | 4.7 | 4.9 | 5.2 | 5.7 | 6.3 | 6.9 | 7.4 | 7.7 | 7.9 |
| 7 | 82 | 19.58 (13.8–34.2) | 6.4 | 0.89 | 6.5 | 4.4 | 8.3 | 6.4 | 0.1 | 1 | 2.2 | 4.7 | 4.9 | 5.2 | 5.7 | 6.4 | 6.9 | 7.5 | 7.8 | 8 |
| 8 | 83 | 21.80 (15.5–42) | 6.2 | 0.98 | 6.3 | 4.4 | 8.9 | 6.4 | 0.1 | 1.1 | 1.9 | 4.7 | 4.9 | 5.2 | 5.8 | 6.4 | 6.9 | 7.6 | 7.8 | 8.1 |
| 9 | 54 | 24.20 (16–38.5) | 6.6 | 0.85 | 6.6 | 4.6 | 8.8 | 6.6 | 0.1 | 1.1 | 1.8 | 4.8 | 5.1 | 5.4 | 5.9 | 6.6 | 7.2 | 7.7 | 8 | 8.3 |
| 10 | 75 | 27.64 (17.8–50) | 6.9 | 0.92 | 7 | 4.9 | 9.1 | 6.9 | 0.1 | 1.1 | 2.1 | 5 | 5.3 | 5.6 | 6.2 | 6.9 | 7.5 | 8.1 | 8.4 | 8.6 |
| 11 | 60 | 30.12 (19.7–53.8) | 7.1 | 1.15 | 7.2 | 4.6 | 10.1 | 7.3 | 0.2 | 0.1 | 2.2 | 5.1 | 5.3 | 5.8 | 6.5 | 7.3 | 8.1 | 8.8 | 9.2 | 9.4 |
| 12 | 64 | 64.33 (21–51) | 7.8 | 1.57 | 7.7 | 4.7 | 11 | 7.8 | 0.2 | 0.9 | 2.6 | 5.2 | 5.5 | 5.9 | 6.8 | 7.8 | 8.9 | 9.8 | 10.3 | 10.6 |
| 13–14 | 70 | 37.60 (21.4–62.1) | 8.8 | 1.93 | 8.7 | 5 | 12.7 | 8.5 | 0.2 | 0.5 | 4 | 5.5 | 5.7 | 6.1 | 7.1 | 8.5 | 10.1 | 11.2 | 11.8 | 12.2 |

Units: Age-years, Weight-kg, SPL-cm.

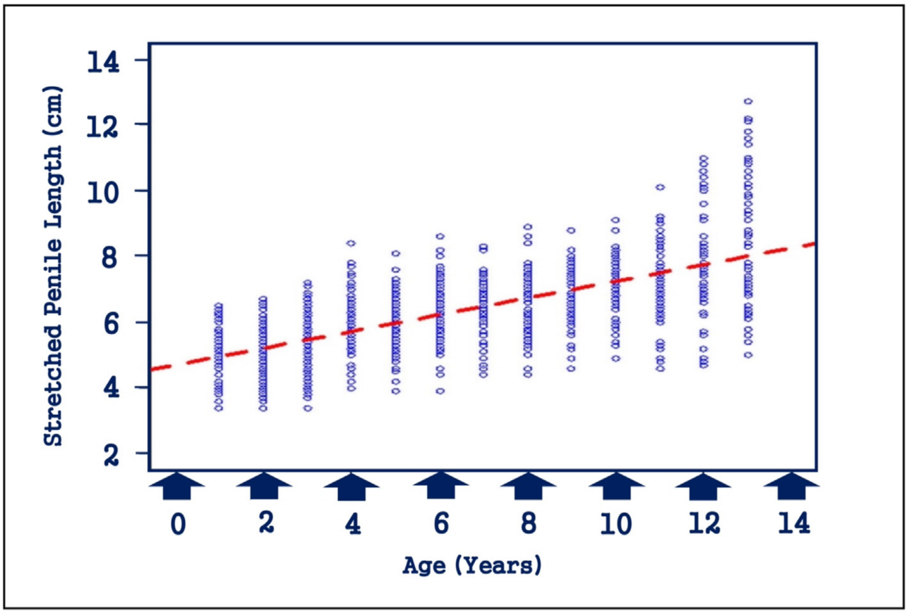


**Fig. 1** Scatter Plot showing the relationship between the age and stretched penile length (SPL (cm) $= 4.69 + 0.25$*age(years), $r = 0.67$, $p < 0.001$).

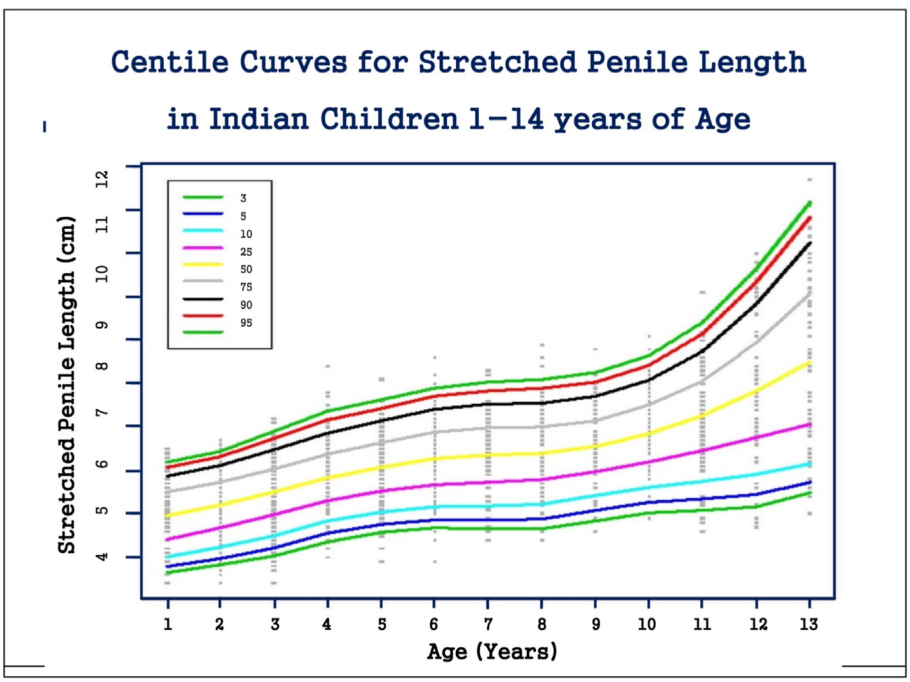


**Fig. 2** Centile curves for stretched penile length for children aged 1–14 years.

## Discussion

Growth charts are a very powerful tool to monitor the growth of children; it displays both the reference values and range of normalcy (centile curves) in a pre-defined population group for growth parameters such as height or weight and growth velocity longitudinally over time. The origin of this concept can be traced back to Count Philibert de Montbeillard who meticulously plotted his son's height till 18 years of age at six-monthly intervals. This first height-growth-curve was published by George Buffon in his Histoire Naturelle [13]. A major statistical development in this direction was the development of the '*law of frequency of errors*' and the understanding that statistically valid data from a population cohort follows a normal distribution pattern which could be summarized into the

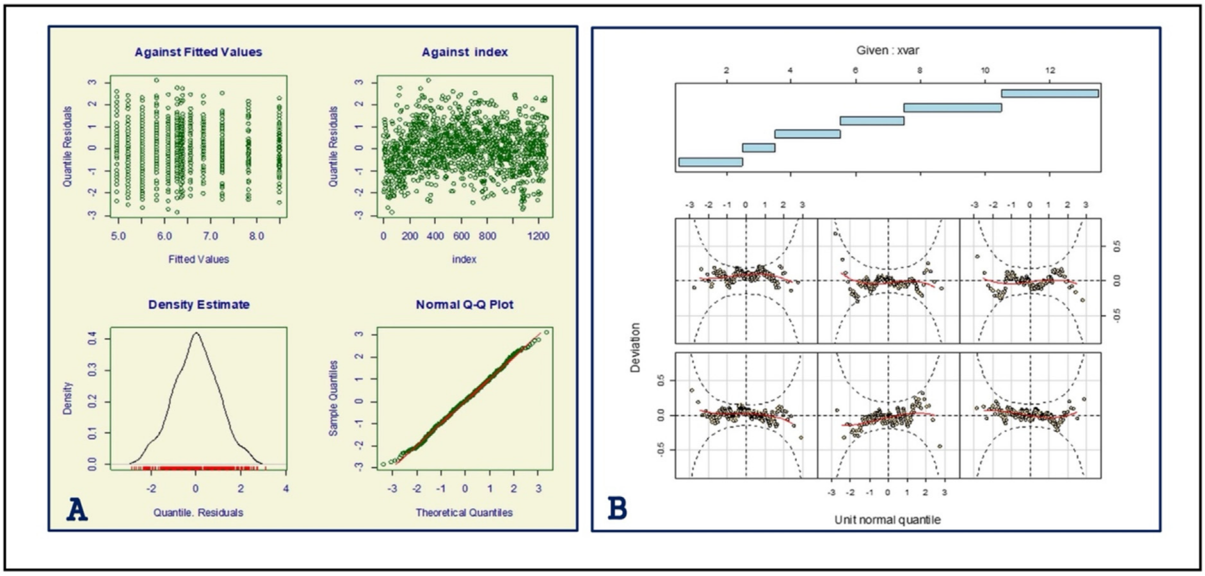


**Fig. 3** **[A]** Normalized Quantile Residual Plot illustrates the behavior of the model. **[B]** Worm Plot shows the goodness of fit of the model at various age- intervals.

mean-value and deviation from the mean (probable error). Galton in 1975 introduced the 'much simpler' concept of percentiles (now centiles) with '*wider applicability*'.

Over time, anthropometric measurements have become an integral to clinical evaluations. The medical literature is abundant with anthropometric data **[PUBMED Advanced search on August 17, 2024, with the search term 'Anthropometry' mined 580,043 results; searching for '(((growth chart) OR centiles) OR normative data) OR anthropometry' mined 623,676 results]**; however, majority of the data relates to common parameters of growth such as height and weight. Little high-quality research is available in the literature pertaining to parameters indicating the growth of external genitalia; data specific to different ethnic groups is even rarer.

It has been said very aptly, 'necessity is the mother of invention'. The authors have witnessed an increasing concern and insecurity amongst the parents over the penile size of their kids (boys) which is in tandem with an increasing number of medical consultations.

Penile length is known to vary with origin/ethnicity [14]; the values can also vary over generations within a population of the same origin or ethnicity [15]. The published studies were based on smaller cohort-sizes [16—18] and the deployed analytics incoherent with that recommended by the World Health Organization for generating Child Growth Standards [19]. A systematic review and meta-analysis to merge the data from the individual studies into a composite synthesis was also limited by the differential age-stratification schemes and availability of data 'per-participant' [20].

Penile size is a crucial indicator of male genital development. Micropenis has been defined as penile length less than 2.5 standard deviations of the age-appropriate mean of SPL. Inherent in the definition of micropenis is the assumption that the mean age-specific SPL is known. Sometimes, it may be the only manifestation of pituitary or hypothalamic hormone deficiencies [21]. Moreover, an early diagnosis of micropenis may lead to early initiation of appropriate measures and a better outlook. The anthropometric SPL data in the pediatric age-group is required for early diagnosis and for monitoring response to treatment [22].

Anthropometric SPL data will also define standards against which the objectivity of parental concerns may be assessed and a distinction may be made between patients who merit work-up and their over-anxious counterparts. It will also confer objectivity to the Marshall & Tanner staging system [23].

Aberrations in penile length may sometimes be the only or the first clinical manifestation of hormonal deficiency arising from the pathology of the hypothalamo-pituitary-gonadal axis. It may also point out underlying genetic syndromes such as Klinefelter syndrome, Noonan syndrome, Kallmann syndrome, Prader—Willi syndrome, and Smith-Lemli-Opitx syndrome. An adrenal tumor may manifest as isosexual precocious puberty and pathological SPL [17]. The penile length has also been found to be useful in the work-up and management of patients with disorders of sex differentiation particularly 46XY patients with ambiguous genitalia and normal testosterone synthesis [24]. Hypospadias repair is one of the key surgeries for a pediatric surgeon or a pediatric urologist. Penile length assessment in hypospadias has significant therapeutic and prognostic implications; it is well-accepted that surgical outcomes do not compare favorably in patients with a small-sized penis. The SPL references will enable evidence-based counseling of parents when their child presents with concurrent hypospadias and micropenis as well as assist the surgeon in making informed decisions such as those related to pre-operative androgen stimulation. The strategic approach to size assessment and management can contribute to better surgical planning and more realistic outcome expectations for both surgeons and parents. Similarly, the parental concerns pertaining to penile length after successful correction may be best addressed by demonstrating a comparison against the reference standards for that age.

The study has witnessed a steady increase in the SPL with age and weight of the child. However, a spurt in penile length has been observed in the age-groups of 2–4 years and 10–14 years (correlating with onset of puberty). The gradual increase in penile length from 5 years of age to the onset of puberty was consistent with that reported in literature [25]. The clinical implication of this observation is significant. The first five years of life are critical to penile growth. Any underlying abnormality in this age-group should be addressed promptly so that the baby does not miss this crucial development window. It may be beneficial to consider penile growth charts alongside height and weight charts for certain patient subgroups.

The authors acknowledge that a longitudinal follow-up on these patients would have been resource-intensive but could have provided valuable insights into patterns of penile growth. Although the study was conducted at a tertiary-care center with a pan-India representation, the footfall from the southern regions of the country was limited [26].

## Conclusions

To the best of the authors' knowledge, this is the largest cross-sectional analysis on the stretched penile length in children. By contributing valuable data to the existing body of knowledge, the study will serve as a useful resource for both parents and physicians in assessing penile growth and development, ensuring that any deviations from the norm are identified and addressed promptly. The centile curves will serve as essential benchmarks in clinical practice, aiding in the early diagnosis of genital abnormalities and facilitate the monitoring of response to treatment during follow-up care.

## Ethics

The study was cleared by the IEC.

The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

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