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ORIGINAL ARTICLE

ESTIMATION OF STATURE USING HAND AND FOOT ANTHROPOMETRY AMONG 2-5 YEARS AGE CHILDREN OF JALPAIGURI, WEST BENGAL, INDIA

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ABSTRACT

Early childhood anthropometry is essential for assessing growth and estimating stature, especially when direct height measurement is not feasible. Hand and foot dimensions are practical alternatives and hold significant relevance in pediatrics and forensic identification. The objectives of the study were to analyze hand and foot anthropometric measurements among Indian children aged 2–5 years and to develop reliable sex-specific and combined regression models for stature estimation.

This cross-sectional study was conducted among 541 children (280 boys, 261 girls) from 25 ICDS centres of Jalpaiguri, West Bengal, India. Hand length, hand breadth, foot length, and foot breadth were measured bilaterally using sliding calipers; stature was measured using a standard anthropometric rod. Descriptive statistics, t-tests, ANOVA, and linear regression analyses were performed. In the present study, the boys showed significantly larger mean values than girls for all measurements ($p<0.05$). All anthropometric variables exhibited significant age-related increases ($p<0.001$). Bilateral differences were negligible. Foot length demonstrated the strongest correlation with stature in boys ($R^2 = 0.891$), girls ($R^2 = 0.868$), and combined samples ($R^2 = 0.880$), with the lowest SEE (3.212–3.440 cm).

The outcome of the study elicited that, hand and foot dimensions, especially the foot length, are reliable predictors of stature in preschool children. These findings have important implications in pediatric assessment, ergonomic design, and forensic identification in mass casualty scenarios.

Keywords: Anthropometry, stature estimation, foot length, hand length, foot breadth, hand breadth, preschool children.

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INTRODUCTION

Stature is a fundamental indicator of body size and an essential parameter in evaluating child growth, nutritional status, body surface area, and pulmonary function (Gould & Rakhir, 2004). In early childhood, accurate assessment of stature is crucial for monitoring physical development, identifying deviations from expected growth patterns, and guiding clinical decision-making. However, direct measurement of in young children can often be difficult due to poor cooperation, illness, or limited availability of proper measuring equipment. In such situations, anthropometric proxy measures, particularly foot and hand dimensions, offer practical and reliable alternatives for estimating stature.

Anthropometric measurements of foot and hand are especially valuable in children aged 2–5 years, a period characterized by rapid skeletal growth, increasing mobility, and significant improvements in fine-motor skills. Foot morphology during this stage is shaped by intrinsic factors such as age, sex, and growth rate, as well as external influences including footwear habits and cultural practices (González-Elena *et al.*, *2021*; Squibb *et al.*, 2022). Hand dimensions show similar age-associated variation and are widely used in pediatric ergonomics, developmental assessment, and prediction research due to their strong association with overall body size (Naczari *et al.*, 2025).

Although international studies have explored foot and hand growth patterns and their utility in estimating stature in children, data for Indian preschool populations remain scarce. Most existing Indian anthropometric research focuses on older children or adults, resulting in a lack of early-childhood reference values and population-specific estimation equations (Kataria, Singh & Kumar, 2024). Given that anthropometric characteristics vary significantly across populations due to genetic, environmental, nutritional, and behavioral factors, datasets from other regions cannot be directly applied to Indian children (González-Elena *et al.*, 2021). India is also a diverse country and to cover population variation children from different part of the country should be studied.

To address this gap, the present study analyzed foot and hand anthropometry of children aged 2–5 years, living in Jalpaiguri, West Bengal, India with a specific focus on developing accurate stature-estimation models.

MATERIALS AND METHODS

This cross-sectional study was conducted across 25 randomly selected Integrated Child Development Scheme (ICDS) centres. A total of **541 children** (280 boys and 261 girls) aged **2–5 years** were included in the analysis. Studied children were Bengalee speakers selected from various villages i.e., Barnesh, Rajarhat, Madhabdanga, Domohoni, Putimari, Dharmapur of Jalpaiguri district, West Bengal, India.

Anthropometric Measurements

Anthropometric measurements of stature was recorded using standard procedures (Weiner & Lourie, 1981). **Hand length** was measured as the linear distance from the distal wrist crease to

the tip of the middle finger. **Hand breadth** was measured as the maximum horizontal distance from the medial border of the thumb to the natural concavity near the palmar digital crease on the lateral side of the index finger.

Foot length was measured as the distance from the *acropodion* (most anterior point of the toe) to the *pternion* (most posterior point of the heel). **Foot breadth** was measured as the distance between the medial and lateral metatarsal points.

Based on these measurements, the following indices were calculated:

Hand Index = (Hand Breadth/Hand Length) x 100.
Foot Index = (Foot Breadth/Foot Length) x 100.

All measurements were taken on both the **right and left sides** using sliding calipers. Foot measurements were taken with the child standing upright on a flat horizontal surface. **Stature** was measured with the child standing barefoot in erect posture using a standard anthropometric rod. Each measurement was recorded **twice**, and the mean value was used in order to minimize intra-observer error. **Age and sex** were verified using the ICDS issued polio immunization cards.

Data Analysis

Data were analyzed using **SPSS version 25** (Statistical Package for the Social Sciences). Sex-specific **means** and **standard deviations** were computed for stature and all hand and foot measurements.

- **Student's t-test** was applied to assess sex differences in hand length, hand breadth, foot length and foot breadth.
- **One-way ANOVA** was performed to determine significant age-related variations across the 2–5-year age groups.
- **Linear regression models** were developed to estimate stature separately for boys, girls, and the combined sample (unknown sex).

A **p-value < 0.05** was considered statistically significant.

RESULTS

Descriptive Statistics of Hand and Foot Dimensions

Table 1 summarizes the mean, standard deviation, and range of hand and foot measurements for boys and girls aged 2–5 years. Across all variables, **boys exhibited higher mean values** than girls for both right and left sides, indicating clear sexual dimorphism in early-childhood anthropometry. For boys, mean right and left hands breadths were 4.98 cm and 4.97 cm respectively, compared to 4.83 cm for girls on both sides. Similarly, boys showed greater hand length (right: 10.72 cm; left: 10.71 cm) than girls (both sides: 10.47 cm).

A similar trend was observed in foot measurements. Boys recorded higher mean right and left foot breadths (6.28 cm and 6.29 cm) than girls (6.05 cm and 6.06 cm). Boys also had longer

feet (mean right and left foot length: 15.37 cm) compared with girls (14.89 cm and 14.90 cm). These findings demonstrate consistent male–female differences across all dimensions studied.

Table 1. Mean, standard deviation (SD), and range of measurements of hands and foots of boys (n = 280) and girls (n = 261)

		Hand breadth (cm)		Hand length (cm)		Foot breadth (cm)		Foot length (cm)	
Sex	Side	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range
Boys	Right	4.98±0.46	4.00-6.20	10.72±1.08	6.40-12.70	6.28±0.59	5.00-8.90	15.37±1.48	11.90-18.20
	Left	4.97±0.45	4.00-6.10	10.71±1.08	6.50-12.60	6.29±0.59	5.00-8.90	15.37±1.48	11.90-18.10
Girls	Right	4.83±0.44	3.80-6.20	10.47±0.96	7.20-13.10	6.05±0.55	4.80-7.20	14.89±1.45	11.40-18.80
	Left	4.83±0.43	3.90-6.20	10.47±0.96	7.10-13.10	6.06±0.54	4.80-7.20	14.90±1.45	11.40-18.80

Sex Differences in Hand, Foot, and Stature Measurements

Independent sample t-tests (Table 2) revealed **significant sex differences** for stature, hand length, hand breadth, foot length, and foot breadth. Boys were significantly taller (96.61 ± 9.69 cm) than girls (94.51 ± 9.45 cm). Significant mean differences were also found for hand length (0.25 cm; $t = 2.808$, $p < 0.01$), hand breadth (0.15 cm; $t = 3.707$, $p < 0.001$), foot length (0.48 cm; $t = 3.799$, $p < 0.001$), and foot breadth (0.11 cm; $t = 4.660$, $p < 0.001$). These results confirm that **all anthropometric variables exhibit sexual dimorphism** in the studied age group.

Table 2. Independent sample t test of hand and foot dimensions between boys and girls boys (n=280) and girls (n=261)

Anthropometric variables (cm)	Mean (SD)		Mean difference	t	95% CI	
	Boys	Girls			Lower	Upper
Stature	96.61±9.69	94.51±9.45	2.10	2.559**	0.488	3.728
Hand Length	10.72±1.08	10.47±0.97	0.25	2.808**	0.074	0.420
Hand Breadth	4.98± 0.46	4.83±0.44	0.15	3.707***	0.067	0.220
Foot Length	15.37±1.48	14.89±1.45	0.48	3.799***	0.232	0.728
Foot Breadth	6.28±0.59	6.17±0.56	0.11	4.660***	0.132	0.325

** = p<0.05 and *** = 0.01

Age and Sex Variation in Anthropometric Parameters

Age and sex specific descriptive statistics for all anthropometric variables are presented in Table 3 and 4. All parameters such as stature, hand length, hand breadth, foot length, foot breadth, and both hand and foot indices showed **progressive increases with age** among both boys and girls. One-way ANOVA showed statistically significant age variation for every variable in both sexes (all $p < 0.01$), indicating **consistent growth patterns** from ages 2 to 5 years. increased markedly across age groups (boys: 86.28 cm at age 2 to 109.05 cm at age 5; girls: 84.09 cm to 106.65 cm). Hand and foot measurements followed a similar trajectory, with older children showing larger dimensions on both sides of the body. Both hand and foot indices also varied significantly across age groups, reflecting proportional changes in breadth–length relationships during growth.

Table 3. Age specific descriptive statistics of hand and foot dimensions of boys.

Boys	2 years (n=83)	3 years (n=72)	4 years (n=77)	5 years (n=49)	Total (n=281)	F
Stature (cm)	86.28± 5.51	93.57± 4.36	102.68± 4.57	109.05± 4.45	96.61± 9.69	288.168***
Right Hand Breadth (cm)	4.60± 0.37	4.83± 0.31	5.24± 0.28	5.45± 0.37	4.48± 0.46	85.195***
Left Hand Breadth (cm)	4.60 ± 0.37	4.82± 0.32	5.21± 0.27	5.44± 0.37	4.97± 0.45	83.891***
Right Hand Length (cm)	9.70± 0.83	10.39± 0.67	11.36± 0.57	11.95± 0.54	10.72± 1.08	142.173***
Left Hand Length (cm)	9.69± 0.82	10.37± 0.67	11.35± 0.59	11.94± 0.54	10.71± 1.08	142.687***
Right Hand Index	47.56± 3.78	46.63± 2.73	46.16± 2.44	45.63± 2.43	46.60± 3.03	5.206**
Left Hand Index	47.56± 3.83	46.60± 2.86	45.97± 2.27	45.57± 2.36	46.56± 3.06	6.572***
Right Foot Breadth (cm)	5.79± 0.42	6.06± 0.35	6.62± 0.43	6.88± 0.42	6.28± 0.59	97.709***
Left Foot Breadth (cm)	5.79± 0.42	6.08± 0.36	6.63± 0.44	6.90± 0.44	6.29± 0.59	97.141***
Right Foot Length (cm)	13.90± 1.01	14.92± 0.89	16.28± 0.77	17.09± 0.75	15.37± 1.48	172.683***
Left Foot Length (cm)	13.90± 1.00	14.93± 0.91	16.30± 0.76	17.08± 0.76	15.37± 1.48	172.376***
Right Foot Index	41.72± 2.00	40.68± 1.89	4.68± 2.13	40.28± 1.48	40.92± 2.00	7.310***
Left Foot Index	41.69± 1.95	40.80± 1.90	4.70± 2.07	40.39± 1.62	40.96± 1.97	6.077**

** = p<0.05 and *** = 0.01

Table 4. Age specific descriptive statistics of, hand, and foot dimensions of girls.

Girls	2 years (n=74)	3 years (n=73)	4 years (n=79)	5 years (n=34)	Total (n=260)	F
Stature (cm)	84.09± 5.47	92.18± 4.09	101.19± 5.18	106.65± 4.63	94.51± 9.45	233.460***
Right Hand Breadth (cm)	4.52 0.39	4.69± 0.32	5.08± 0.37	5.24± 0.31	4.83± (0.44)	49.529***
Left Hand Breadth (cm)	4.53± 0.39	4.69± 0.32	5.07± 0.36	5.23± 0.30	4.83± 0.43	47.084***
Right Hand Length (cm)	9.57± 0.80	10.27± 0.53	11.04± 0.66	11.54± 0.63	10.47± 0.96	93.547***
Left Hand Length (cm)	9.56± 0.79	10.27± 0.52	11.04± 0.65	11.54± 0.64	10.47± 0.96	95.655***
Right Hand Index	47.42± 3.56	45.69± 2.64	46.05± 2.44	45.52± 2.53	46.27± 2.95	5.884**
Left Hand Index	47.59± 4.00	45.72± 2.54	45.95± 2.49	45.40± 2.45	46.28± 3.17	6.480***
Right Foot Breadth (cm)	5.60± 0.42	5.89± 0.43	6.41± 0.42	6.54± 0.30	6.05± 0.55	67.922***
Left Foot Breadth (cm)	5.62± 0.41	5.90± 0.42	6.40± 0.43	6.55± 0.31	6.06± 0.54	64.875***
Right Foot Length (cm)	13.43± 0.96	14.61± 0.83	15.87± 1.05	16.38± 0.86	14.89± 1.45	117.122***
Left Foot Length (cm)	13.44± 0.97	14.59± 0.84	15.89± 1.05	16.42± 0.85	14.90± 1.45	119.124***
Right Foot Index	41.78± 2.10	40.32± 1.89	40.44± 1.92	40.00± 1.76	40.73± 2.05	10.332***
Left Foot Index	41.87± 2.20	40.47± 1.92	40.31± 1.89	39.95± 1.86	40.75± 2.05	11.961***

** = $p<0.05$ and *** = 0.01

Bilateral Differences in Hand and Foot Dimensions

Analysis of right–left measurements revealed **minimal bilateral differences** across all hand and foot variables (Table 5). For boys, right and left-hand breadths were nearly identical (4.98 vs. 4.97 cm), and hand length showed only a 0.01 cm difference (10.72 vs. 10.71 cm). Girls also showed no measurable bilateral variation in hand breadth (4.83 vs. 4.83 cm) or hand length (10.47 vs. 10.47 cm).

Similarly, foot dimensions exhibited high symmetry. Boys showed almost identical foot breadths (6.28 vs. 6.29 cm) and equal foot lengths (15.37 vs. 15.37 cm). Girls displayed similarly small differences (foot breadth: 6.05 vs. 6.06 cm; foot length: 14.89 vs. 14.90 cm).

These findings indicate **very low right–left asymmetry** in the hand and foot measurements of children aged 2–5 years. The bilateral measurements were therefore treated as independent but interchangeable for subsequent analyses.

Table 5. Bilateral difference using independent t-test analyses.

Paired sample		Boys			Girls		
		t	df	*P* value	t	df	*P* value
Pair 1	RHB - LHB	2.969	280	0.003	.448	259	0.654
Pair 2	RHL - LHL	2.969	280	0.004	1.361	259	0.175
Pair 3	RFB - LFB	-2.262	280	0.024	-1.037	259	0.301
Pair 4	RFL - LFL	-.607	280	0.544	-.971	259	0.333

Regression Analysis for Stature Estimation

Simple linear regression models (Table 6) were developed to estimate stature using hand and foot dimensions as predictors.

Table 6. Linear regression analysis and estimation of stature from foot and hand dimensions.

Gender	Variables	Equation	R	R^2	SEE	t	p value
Boys	Hand Length	8.199 + (0.218)	0.914	0.835	3.944	37.605	0.000
	Hand Breadth	16.983 + (0.741)	0.808	0.652	5.720	22.934	0.000
	Foot Length	6.161 + (0.129)	0.944	0.891	3.212	47.679	0.000
	Foot Breadth	13.821 + (0.525)	0.844	0.713	5.206	26.321	0.000
Girls	Hand Length	9.047 + (0.233)	0.924	0.853	3.621	38.851	0.000
	Hand Breadth	16.135 + (0.880)	0.752	0.566	6.245	18.336	0.000
	Foot Length	6.060 + (0.147)	0.932	0.868	3.440	41.231	0.000
	Foot Breadth	14.432 + (0.586)	0.838	0.702	5.175	24.642	0.000
Unknown	Hand Length	8.559 + (0.159)	0.919	0.844	3.809	53.979	0.000
	Hand Breadth	16.547 + (0.562)	0.785	0.616	5.971	29.433	0.000
	Foot Length	6.069 + (0.097)	0.938	0.880	3.343	62.797	0.000
	Foot Breadth	13.904 + (0.385)	0.841	0.708	5.213	36.122	0.000

All regression coefficients were statistically significant ($p < 0.001$) for boys, girls, and the combined (unknown sex) sample. Among the measured variables, **foot length emerged as the strongest predictor of stature** for all groups. It showed the highest coefficients of

determination (boys: $R^2 = 0.891$; girls: $R^2 = 0.868$; unknown: $R^2 = 0.880$) and the lowest standard errors of estimation (SEE) (boys: 3.212; girls: 3.440; unknown: 3.343).

Hand length also demonstrated strong predictive power, particularly when sex-specific models were applied (boys: $R^2 = 0.835$; girls: $R^2 = 0.853$). Foot breadth and hand breadth yielded lower R^2 values and higher SEE compared with length-based measures, although still statistically significant. These findings confirm that **foot length is the most efficient and reliable predictor of stature** among children aged 2–5 years.

DISCUSSION

The present study assessed hand and foot anthropometry among Indian preschool children aged 2–5 years and evaluated their usefulness in estimating stature. The findings demonstrate **significant sexual dimorphism, consistent age-related growth patterns**, and **strong correlations between stature and both hand and foot dimensions**, confirming their applicability in pediatric and forensic contexts.

Sexual Dimorphism in Hand and Foot Dimensions

The results show that boys have consistently larger hand and foot measurements than girls across all age groups and on both sides of the body. This pattern of early sexual dimorphism, though subtle, aligns with previous studies conducted among Indian and non-Indian children, which also report greater mean anthropometric dimensions in boys (Chavan *et al.*, 2012; Puszczalowska-Lizis & Lizis, 2022). The observed differences may reflect early variations in growth velocity, hormonal influence, and body composition between male and female children.

Age-Related Increase in Anthropometric Measurements

Significant age-based variation was found for stature, hand length, hand breadth, foot length, and foot breadth in both sexes. These findings confirm the progressive and predictable increments expected during the preschool period, consistent with growth patterns described by Bayat et al. (2015) and Singh et al. (2019). The hand and foot indices also showed significant variation with age, suggesting proportional developmental changes in breadth–length ratios during early childhood. Such patterns underscore the importance of age-specific anthropometric references for preschool children.

The present study found minimal bilateral differences in all hand and foot measurements, with right–left differences ranging from 0.00 to 0.02 cm. Such negligible asymmetry suggests that children aged 2–5 years exhibit a high degree of bilateral morphological symmetry. This is expected in early childhood, as strong patterns of functional dominance (handedness or footedness) typically become more pronounced in later childhood.

These results agree with earlier pediatric anthropometric research that reports limited directional asymmetry during early growth stages, when bilateral limbs perform similar developmental and functional roles (Singh *et al.*, 2019). The high degree of symmetry also supports the practical use of either hand or either foot in stature-estimation models, particularly

in contexts where measurements from only one side may be available—for example, in clinical assessments, field surveys, or forensic scenarios involving incomplete remains.

Stature Estimation and Predictive Potential of Measurements

One of the principal aims of the study was to evaluate the utility of hand and foot measurements in stature estimation. All regression models were statistically significant; however**, foot length emerged as the single strongest predictor** in boys, girls, and the combined sample. Foot length consistently showed the highest coefficients of determination (R^2) and the lowest standard errors of estimation (SEE), indicating greater accuracy and stability compared with hand length, hand breadth, or foot breadth. The highest degree of correlation found between height and foot length (r = 0.919) whereas hand breadth shows the lowest degree of correlation with height (r = 0.785) among unknown samples.

These findings align with earlier research demonstrating that foot length is one of the most reliable body parameters for predicting in children and adults (Krishan, 2008; Vangara *et al.*, 2019 and Bafor, Chibuzom & Mbanuzuru, 2023). The biomechanical rationale lies in the fact that foot length grows in close synchrony with long bone development and overall skeletal growth. Hand length also showed strong associations with stature, supporting previous findings in pediatric populations (Ibegbu *et al*., 2013; 2015; Charmode, Kadlimatti, & Pujari, 2019). Together, these results reinforce the usefulness of hand and foot anthropometry in situations where direct measurement is not feasible, such as in bedridden children, field surveys, mass casualty events, or forensic examinations involving fragmented remains.

Comparison with Previous Studies

The magnitude of correlations observed in the present study is comparable to studies conducted in other Indian states like Maharashtra (Chavan *et al*., 2012), Uttar Pradesh (Singh *et al*., 2019), Andhra Pradesh (Vangara *et al*., 2019), Telangana (Vanishri & Seikh, 2017), as well as international studies from Nigeria (Ibegbu *et al*., 2013, 2015), Iran (Opoola *et al*., 2024) and Egypt (Mahammed *et al*., 2024). Across populations, foot length consistently demonstrates superior predictive value relative to breadth-based measurements, further validating the findings of this study.

The age group examined 2 to 5 years is less commonly studied compared to older children. Therefore, this study fills an important gap by providing early-childhood anthropometric data and confirming that stature prediction can be reliably performed even in younger age groups.

The results have several practical implications:

- **For pediatrics and public health,** stature-estimation equations from this study can help track growth, detect anomalies, and support nutritional assessment.
- **For ergonomics and product design,** such data contribute to developing appropriately sized footwear, gloves, and school-related tools for preschool children.
- **For forensic science,** stature-estimation equations derived from hand and foot dimensions can assist in identifying young children in cases involving disasters, missing persons, or decomposed remains.

CONCLUSION

In summary, this study demonstrates that **hand and foot dimensions are strong predictors of stature in Indian preschool children,** with foot length being the most reliable single predictor. These findings support their utility in pediatric health assessment, ergonomic design, and forensic identification involving young children. The study provides valuable baseline data and highlights the need for broader, multi-region anthropometric databases for Indian children.

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CONFLICTS OF INTEREST

The authors have no conflict of interests.

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