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Sex determination using odontometric and anthropometric dimensions of 5-6-year-old children*

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Abstract

Introduction: Forensic dentistry encompasses the handling, examination, and evaluation of dental evidence within a criminal justice context. It deals with the dental evidence obtained from various events such as road accidents, natural calamities, illegal activities, and crime scenes. Studies to assess the sexual dimorphism in children, especially using odontometric and anthropometric measurements, have rarely been published. Therefore we designed this study to evaluate sexual dimorphism using odontometric and anthropometric parameters in children from Tamil Nadu. **Materials and methods:** The present study was conducted on 63 female and 50 male children aged 5-6 years. Linear measurements for Mesio Distal Width, Inter Canine Distance, Index Finger Length, Ring Finger Length, Foot Breadth and Foot Length were made. Maxillary Canine Index, Mandibular Canine Index, Hand Index, and Foot Index were calculated from these linear measurements. Statistical Package for the Social Science version 20.0 software was used for statistical analysis. **Results and conclusion:** Sexual dimorphism was evident in most odontometric and anthropometric parameters in children. Using a combination of odontometric and anthropometric parameters in an equation for gender determination in children resulted in better accuracy. We derived two formulae for sex determination using discriminant function analysis. Their accuracies were 75.2% and 81.4%.

Keywords: forensic anthropology; linear measurements; discriminant function analysis

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Introduction

Accurate sex identification of human remains can significantly narrow down the search to a specific sex, thus providing a direction for forensic investigation. Although various methods for sex identification in skeletal remains exist, methods involving teeth are preferred especially when there are no long bones for investigation. Odontometry involves measuring the dimensions of the teeth. Linear measurements like Mesio-distal and Bucco-lingual tooth dimensions and other measurements like Incisor index, Crown index, Maxillary Canine Index and Mandibular canine index have been shown to exhibit sexual dimorphism (1). Anthropometry is the collection and correlation of systematic measurements of human individuals including body weight, size, and shape. Anthropometrical dimensions of human remains have been used in sex determination in the past. Finger proportion was found to be a dimorphic and biometric populace marker (2). Likewise, foot dimensions such as Foot Length and Breadth have been employed for predicting the sex of a person (3).

Recent studies have reaffirmed the utility of both odontometric and anthropometric parameters in estimating sex across different age groups and populations (4-10). However, the majority of these investigations have been conducted in adult cohorts, with relatively few exploring sexual dimorphism in the primary dentition or early childhood.

In children, teeth and basic anthropometric structures are less influenced by secondary sexual characteristics, making them potentially reliable indicators of sexual dimorphism even before puberty. Despite this, limited literature exists that simultaneously examines both odontometric and anthropometric parameters for sex determination in children, particularly within the Indian population (10). Therefore, this study was designed to fill this gap by evaluating sexual dimorphism using odontometric and anthropometric dimensions among 5–6-year-old children from Tamil Nadu. Furthermore, we aimed to derive discriminant function equations combining these parameters to enhance the accuracy of sex determination in forensic and anthropological contexts.

Materials and methods

A cross-sectional study was carried out on 113 children [50 male and 63 female] belonging to the state of Tamil Nadu. Only children with a complete and fully erupted primary dentition, visiting the Pediatric and Preventive Dentistry

department of our institution or belonging to various government primary schools, were included in the study. Only children between 5 and 6 years of age and with normal growth of hands and foot were included. Children with partially erupted teeth, restorations, grossly destructed teeth, avulsed teeth, fracture, excessive wear or teeth with inherited deformities, syndrome with alterations in tooth eruption and with anomalies of hands and foot were not included. The exclusion of children presenting with dental anomalies, developmental disorders, or deformities of the hand or foot was based on the rationale that such variations can significantly alter the dimensions of odontometric and anthropometric parameters, potentially leading to bias in discriminant function analysis. These exclusions ensured that the measurements reflected normal developmental variation rather than pathological differences.

We calculated the odontometric and anthropometric parameters using the criteria proposed by Sivakumar et al. (11). The Mesiodistal Width (MDW) was recorded between the contact points of the tooth on the right and left side and the Inter canine distance (ICD) was recorded as the distance between the cusp tips of the right and left canine (Figures 1 and 2). From these two measurements, the Canine Index for right and left side was determined as: Canine Index = MDW / ICD.

Index Finger Length (IFL) was recorded as the distance between the proximal-most point at the base and the distal end of the index finger at the midpoint and the Ring Finger Length (RFL) was recorded along the midline on the palmar surface at proximal to the distal end of ring finger. (Figure 3). From these two values, the Hand Index for right and left sides was determined using the formula: Hand Index = IFL / RFL.

Foot breadth (FB) was measured between the tips of the metatarsal bone, namely metatarsal fibulare laterally and metatarsale tibiale medially. Foot length (FL) was measured between acropodion and pternion. From these two measurements, the Foot Index was determined for both sides using the formula: Foot Index = (FB / FL) × 100.

Statistical Package for the Social Science version 20.0 software was used for statistical analysis. Descriptive statistics was used to determine the mean and Standard deviations of the odontometric and anthropometric parameters. Independent sample t-test was performed to compare the right and left Mesio Distal Width (MDW) of canine, Inter Canine Distance (ICD),



Figure 1. Images showing the measurement of mesiodistal width of canine made using fine tips of divider.



Figure 2. Images showing the measurement of inter canine distance made using the fine tips of the divider.



Figure 3. Images showing anthropometric measurements of fingers using a digital vernier caliper.

Table 1. Mean, SD, t value, p value and 95% confidence interval of all parameters.

Parameters	Sex	Sample Size (n)	Mean	Standard Deviation (SD)	t value	Significance (p value)	95% Confidence Interval of The Difference	
							Lower	Upper
MDW 53	Male	50	7.64	0.48	4.572	<0.001	0.24	0.62
	Female	63	7.20	0.51				
MDW 63	Male	50	7.64	0.48	4.57	<0.001	0.24	0.62
	Female	63	7.20	0.51				
MDW 73	Male	50	6.50	0.50	4.66	<0.001	0.23	0.57
	Female	63	6.09	0.38				
MDW 83	Male	50	6.50	0.50	4.69	<0.001	0.23	0.57
	Female	63	6.09	0.38				
Max ICD	Male	50	31.74	2.02	2.94	0.004	0.33	1.71
	Female	63	30.71	1.66				
Man ICD	Male	50	24.78	1.93	2.46	0.015	0.15	1.46
	Female	63	23.96	1.57				
R Max CI	Male	50	0.2412	0.016	1.77	0.079	0.0007	0.012
	Female	63	0.2351	0.019				
L Max CI	Male	50	0.2412	0.016	1.77	0.079	0.0007	0.012
	Female	63	0.2351	0.019				
R Man CI	Male	50	0.2633	0.023	1.94	0.054	0.0001	0.016
	Female	63	0.2551	0.020				
L Man CI	Male	50	0.2633	0.023	1.94	0.054	0.0001	0.016
	Female	63	0.2551	0.020				
Right IFL	Male	50	47.43	3.45	2.07	0.04	0.05	2.50
	Female	63	46.15	3.10				
Left IFL	Male	50	47.40	3.08	2.90	0.004	0.51	2.72
	Female	63	45.78	2.84				
Right RFL	Male	50	48.99	3.38	3.17	0.002	0.76	3.29
	Female	63	46.96	3.36				
Left RFL	Male	50	49.24	2.97	1.47	0.144	0.31	2.12
	Female	63	48.34	3.45				
RHI	Male	50	0.9698	0.059	1.447	0.15	0.033	0.005
	Female	63	0.9840	0.045				
LHI	Male	50	0.9632	0.040	1.816	0.072	0.0013	0.030
	Female	63	0.9487	0.043				
Right FL	Male	50	175.84	8.63	4.96	<0.001	5.31	12.36
	Female	63	167.00	9.95				
Left FL	Male	50	176.72	8.67	4.53	<0.001	4.48	11.43
	Female	63	168.76	9.69				
Right FB	Male	50	70.00	3.74	5.66	<0.001	2.97	6.17
	Female	63	65.42	4.83				
Left FB	Male	50	68.96	4.74	5.81	<0.001	3.73	7.58
	Female	63	63.30	5.42				
RFI	Male	50	39.83	1.57	1.473	0.144	0.207	1.406
	Female	63	39.23	2.70				
LFI	Male	50	39.01	1.65	3.676	<0.001	0.686	2.294
	Female	63	37.52	2.62				

Maxillary canine index (MCI), Mandibular canine index (MCI), Hand index (HI) and Foot index (FI). A p-value of < 0.05 was considered to be significant. Percentage of sexual dimorphism was determined using the formula proposed by Garn et al. (12).

Percentage of sexual dimorphism (PSD) = $\{(\text{mean values of male children} - \text{mean values of females}) / \text{mean values of females}\} \times 100$.

A positive value for PSD suggests that a higher dimension was seen in male children, and vice versa. All measurements were recorded by a single examiner who underwent prior calibration and training under expert supervision. The examiner practiced measurement techniques on a pilot group before data collection to ensure consistency. Random measurement checks were periodically verified during the study to maintain precision. This procedure minimized potential observer bias and ensured methodological reliability. Stepwise discriminant function analysis was employed to identify the variables that contributed most significantly to sex differentiation. Parameters were selected for inclusion in the discriminant model based on their statistical significance ($p < 0.05$) in univariate analysis, Wilk's Lambda values, and discriminant loadings. This approach minimized redundancy and maximized model accuracy for sex prediction. Two formulae were obtained by discriminant function analysis, and their accuracies were assessed.

Results

The mesiodistal width and inter-canine distance of right and left primary canine were found to be statistically higher in males compared to females whereas in right and left maxillary and mandibular canine indices did not show any statistically significance difference. On comparing the Index and Ring Finger Length of the right and left hand between males and females, the length of the finger was larger in males compared to females, and the results were found to be statistically significant. However, on comparing the hand indices, the results showed no significant difference. We also found that foot length and breadth in the right and left foot were higher in males compared to females and statistically significant results were observed. On comparing the foot indices, the left foot index was significantly greater in males than females. However, there was no significant difference in the Right Foot Index (RFI) between the two groups (Table 1). These findings collectively

demonstrate that sexually dimorphic traits can be identified reliably even in early childhood, using both dental and somatic measurements. Such differences, though subtle at this age, can aid preliminary sex estimation in forensic cases involving fragmented or juvenile remains, particularly when long bones or pelvic structures are unavailable (4).

Using stepwise discriminant function analysis, we derived two formulae for sex determination. Using Wilk's lambda, we found that all the predictor variables were statistically significant. The first formula used only the dental morphometric parameters, while the second formula used both odontometric and anthropometric parameters (Table 2).

The formula derived using statistically significant odontometric parameters was:

$$X = -19.234 + 0.687 \text{ MDW53} + 1.274 \text{ (MDW73)} + 0.152 \text{ (MaxICD)} + 0.059 \text{ (ManICD)}$$

The formula derived using both odontometric and anthropometric parameters were as follows:

$$X1 = 0.382 + 0.542 \text{ (MDW53)} + 0.915 \text{ (MDW73)} + 0.610 \text{ (MaxICD)} - 0.119 \text{ (ManICD)} - 0.202 \text{ (Right IFL)} + 0.144 \text{ (Left IFL)} - 0.42 \text{ (Right RFL)} + 0.113 \text{ (Right FL)} - 0.207 \text{ (Left FL)} + 0.025 \text{ (Right FB)} + 0.449 \text{ (Left FB)} - 0.584 \text{ (LFI)}$$

The cut-off points between the sexes in odontometric and combined odontometric/ anthropometric formulae were 0.117 and 0.195 respectively. Centroid values were also obtained for both formulae (Tables 3 and 4). After substituting the values in the formula, if the acquired value (X) is closer to the male value, the sample should be recorded as male, and vice versa. The statistical jackknife accuracy obtained for both the formulae was 75.2% and 81.4% respectively. The higher discriminant accuracy obtained when odontometric and anthropometric parameters were combined (81.4%) highlights the value of multi-parameter analysis in forensic sex estimation. This suggests that even in cases involving incomplete juvenile remains, integrating dental and limb measurements may enhance the likelihood of correct sex identification. Such equations could serve as reference tools for regional forensic databases or preliminary screening in mass disaster victim identification where pediatric samples are involved (10).

Discussion

We found that all primary canines had greater MDW in males compared to females. This result is similar to those reported in previous studies (10, 13). However, our findings are in contrast to

Table 2. Discriminant function analysis for all the statistically significant parameters.

Parameters	Wilk's Lambda	F	df1	df2	Significance (p value)
MDW 53	0.842	20.903	1	111	<0.001
MDW 73	0.828	23.118	1	111	<0.001
Max ICD	0.927	8.693	1	111	0.004
Man ICD	0.948	6.059	1	111	0.015
Right IFL	0.963	4.310	1	111	0.040
Left IFL	0.929	8.424	1	111	0.004
Right RFL	0.917	10.060	1	111	0.002
Right FL	0.818	24.682	1	111	<0.001
Left FL	0.843	20.607	1	111	<0.001
Right FB	0.786	30.253	1	111	<0.001
Left FB	0.766	33.822	1	111	<0.001
LFI	0.901	12.217	1	111	0.001

F – Test Statistics; df1 – degree of freedom 1; df2 – degree of freedom 2.

Table 3. Function at group centroids and statistically observed jackknife accuracy for the equation X.

Functions at group centroids		Cut- off point value	Statistically observed jackknife accuracy for this equation
Sex	Function (1)		
Male	0.567	0.117	75.2%
Female	-0.450		

Table 4. Function at group centroids and statistically observed jackknife accuracy for the equation X₁.

Functions at group centroids		Cut- off point value	Statistically observed jackknife accuracy for this equation
Sex	Function (1)		
Male	0.945	0.195	81.4%
Female	-0.750		

the findings observed by Kuswandari et al., who reported that females showed higher mesiodistal width than males (14). Similar results with higher MDW in males were observed in the permanent dentition by several studies in the past (7, 8, 15-17).

When analyzing the results of ICD in primary dentition, we observed that male children had significantly larger ICDs than female children. No such studies comparing ICD in primary dentition have been reported till date. However, similar results were observed in the permanent dentition by several studies in the past (7, 8, 15-17). Contrasting findings were reported by Singh et al. who observed that there was no significant difference in ICD between males and females (8). On analyzing the results of the Maxillary Canine Index (MaxCI) and Mandibular Canine Index (Man CI), we observed no significant difference between male and female children. No studies compare CI primary dentition. In permanent dentition, similar results were obtained by Singh et al., who reported that there was no statistically significant difference in CI between males and females (8). Our findings are in contrast to the

results obtained by several studies in the past, which observed that males had larger CI than females in permanent dentition (15-17).

On analyzing the IFL and RFL in children, we observed that males had larger IFL and RFL than females. The results showed a statistically significant difference in IFL and RFL in the right and left hand except in the Left RFL. This result is similar to the results obtained by Buru et al., who reported that there is a statistically significant difference in IFL, RFL, and LFL (Little Finger Length) (18). Contrasting findings were reported by Hohendorff et al., who reported that there was no significant difference in finger length between males and females (19). Similar results were observed in the adults by previous studies in the past, which observed that males had larger IFL and RFL than females (20-22). Comparable findings have also been reported by Gupta et al., who demonstrated significant sexual dimorphism in adult hand dimensions, further supporting the forensic applicability of hand measurements for sex determination (23). Jee et al. reported that in addition to IFL and RFL, the length of all other three fingers in the right and left hand showed a

significantly higher difference in males than females (20). Another study by Sehrawat et al., reported that the thumb finger showed the highest sexual dimorphism (4).

We observed statistically insignificant difference in HI in the right hand and left hand between male and female children. Alternative findings were reported by Buru et al. and Mitsui et al., who found that there is a statistically significant difference between the two groups (18, 21). Similar results were reported in adults by Sen and Assi, who observed statistically insignificant difference in HI (2, 22). Alternative findings were observed by Sarkodie et al. and Singh et al., who reported a statistically significant difference in HI (9, 24).

On analyzing the foot length and breadth in children, we observed that sexual dimorphism persisted. Males had larger FL and FB than females and their results were statistically significant. Similar results were reported in previous studies (5, 6). Contrasting findings were observed by Vrdoljak, who reported that there was no significant difference in FL between males and females (25). Similar results were observed in adults by several studies in the past who reported that adult males showed higher FL and FB than adult females (26-28).

We observed that Left FI was larger in males than females. However, there was insignificant difference in Right FI between the male and females. No such studies compare FI in children. Kumari and Raza reported no significant difference on comparing FI (29). Agnihotri et al. and Zeybek et al. reported a statistically significant difference in FI between males and females (26, 27).

Upon assessing the values of tooth parameters which are statistically significant with stepwise discriminant function analysis, an equation [X] was derived with centroid values, which showed a jackknife accuracy of 75.2%. This jackknife accuracy of 75.2% was significantly higher when compared to the equation developed by Black, whose equation showed an accuracy ranging from 33.3% to 75% (13). In a study by Thirumal et al., they derived six equations using all the primary teeth and observed jackknife accuracy ranging from 87.5% to 99.8% (10). However, we derived the equation only by using primary canine parameters and obtained a jackknife accuracy of 75.2%. Using permanent canines, several studies in the past derived an equation for sex determination and their accuracies range from 55% to 78% which is similar to or lesser than our accuracy (15-17).

Using anthropometric parameters of the hand in adults, Sen and Sarkodie et al. derived an equation for sex determination and found the accuracy ranging from 60% to 75% (2, 24). Using foot parameters in adults, Suleiman et al. derived an equation that resulted in an accuracy of 72.5% and 71.2% (28). However, our equation shows an accuracy of 81.4% which suggests that using a combination of anthropometric and dental morphometric parameters results in better accuracy. However, Zeybek et al., using right and left foot parameters reported an accuracy of 95.6% and 96.4% respectively (27). Recent studies have also demonstrated that incorporating multiple morphometric variables enhances the precision of sex determination models, even in young populations (5, 7, 9, 24). Our findings indicate that sexual dimorphism is detectable as early as 5–6 years of age, before the onset of puberty. This reinforces the potential forensic application of such measurements in age groups where skeletal dimorphism is not yet pronounced. In forensic cases involving fragmented remains or mass disasters, the ability to determine sex from primary teeth or small body parts such as hands and feet can significantly improve identification efficiency. Therefore, population-specific equations like those derived in this study can serve as valuable reference tools in pediatric forensic anthropology.

The present study is limited by its relatively small sample size and geographic restriction to children from Tamil Nadu, which may affect generalizability to other populations. Additionally, only two-dimensional linear measurements were analyzed; three-dimensional or volumetric odontometric data could potentially improve model accuracy. Future research with larger, multi-regional samples and advanced imaging techniques such as 3D scanning or CBCT is recommended to validate and expand upon these findings.

Conclusion

We conclude that there is a significant sexual dimorphism exhibited in odontometric and anthropometric parameters in children. This can be used for forensic investigations in gender determination. Using a combination of odontometric and anthropometric parameters in an equation for sex determination in children resulted in better accuracy. The efficacy of the derived equations for sex determination in population from various parts of the country needs to be further studied.

The present findings indicate that even in children as young as 5–6 years, measurable dimorphism exists in teeth, fingers, and feet, which can serve as valuable adjuncts in forensic identification. The discriminant function equations developed in this study - particularly the combined odontometric and anthropometric model (81.4% accuracy) - can be utilized as preliminary tools for sex estimation in juvenile remains when skeletal or pelvic indicators are unavailable.

Forensic practitioners and clinicians can apply these models during early identification stages in cases involving mass disasters, child homicide, or unknown juvenile remains. Incorporating such region-specific morphometric databases into forensic workflows can enhance accuracy and efficiency in age- and sex-based profiling.

Future studies with larger, multi-regional, and ethnically diverse samples are recommended to establish comprehensive pediatric morphometric standards and to validate these discriminant equations across populations. Integration of three-dimensional or digital imaging technologies could further improve measurement precision and forensic applicability.

Declaration of Interest

None

Author Contributions

Sivakumar Pradap- Concepts, Design, Definition of intellectual content, Literature search, Data acquisition, Data analysis, Manuscript preparation, Manuscript editing, Manuscript review, Guarantor.

Harikrishnan Prasad- Concepts, Design, Definition of intellectual content, Literature search, Data acquisition, Data analysis, Manuscript preparation, Manuscript editing, Manuscript review, Guarantor.

Muthusamy Rajmohan- Manuscript editing, Manuscript review, Data analysis

Kenniyankumar SriChinthu- Manuscript editing, Manuscript review, Concepts

Viswanathan Prema- Manuscript editing, Manuscript review, Design

Sivanandhan Shanmuganathan- Manuscript editing, Manuscript review, Definition of intellectual content.

Statement on the use of artificial intelligence in manuscript preparation

Artificial intelligence was not used in the preparation of this manuscript.

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