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A STUDY ON THE RELIABILITY OF COMBINED WIDTH OF MAXILLARY ANTERIOR TEETH, MAXILLARY CANINE WIDTH, HEAD CIRCUMFERENCE, INNER CANTHAL DISTANCE, INTER-ALAR WIDTH AND SKULL DIAMETER IN SEX AND STATURE DETERMINATION

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ABSTRACT

Background: Identity of an individual can be determined by its sex, age, height, and ancestry background. This becomes important in many of the medicolegal cases where identity of the deceased has to be established. Craniometry is a vital tool in making a precise and systematic measurement of human skull, so as to deduce sex and height of dead individuals. Teeth are also very important elements in the identification of skeletal remains.

Aims: To assess the sex and height based on different craniometric and odontometric parameters in Uttar Pradesh population.

Materials and Methods: The study was carried out on 180 patients, 90 males and 90 females. The measurements were obtained for combined mesiodistal width of maxillary anterior teeth, right and left maxillary canine width, head circumference, inner canthal distance, inter-alar width, and skull diameter with the help of Vernier caliper, spreading caliper and a non stretchable measuring tape. Linear regression equations and correlation coefficients were derived for gender and height based on the above parameters.

Results: All recorded craniometric and odontometric measurements were significantly different between males and females ($p<0.05$). The ratios of measurements were also significantly different among males and females ($p<0.05$) except for head circumference to combined mesiodistal distance of maxillary anterior teeth and height to skull diameter.

Head circumference significantly predicted the height of male and female, with the regression equations for males (height=113.70+0.97 x head circumference, p=0.03) and females (height=74.78+1.55 x head circumference, p=0.0001). While inner canthal distance predicted significantly only the height of males (height=149.73+0.57 x inner canthal distance, p=0.04). However, the combined data of males and females showed highly significant prediction of height by all craniometric parameters (p= 0.0001), and significant prediction by right and left maxillary canine width (odontometric parameters) ($p<0.005$) but not by combined mesiodistal width of maxillary anterior teeth which had no significant contribution in height estimation.

Key words: Craniometry, head circumference, height, inner canthal distance, odontometry, sex determination, stature estimation.

INTRODUCTION

United Nations declaration of human rights states that every freeborn person has the right to be identified even after death.[1] Biological identity of an individual can be determined by its sex, age, stature (height) and ancestry background. Identification of a corpse becomes a prerequisite in cases of precipitous and unforeseen demise, fires, explosions, railway or aircraft accidents, mutilated or hidden decomposed bodies, or foul

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play. Out of the four biological indicators of identity, assessment of sex particularly has significant contribution in construction of a physical profile of the decedent.[2] By knowing the sex, identification becomes simplified because then only missing persons of one sex need to be considered. In this sense identification of sex takes precedence over age.[3]

Sex determination from the cranium bones relates to their size, robustness and some metrical characteristics. Male and female skulls may be distinguished by general size, supraorbital ridges, mastoid processes, occipital region, frontal eminences, parietal eminences, orbits, forehead, cheek bones, palate, occipital condyles, mandible, chin shape, gonial angle and gonial flare. Thus, craniofacial anthropometry is a vital tool in making a precise and systematic measurement of human skull, so as to deduce sex of dead individuals.[4]

Among the various craniometrical dimensions, the most important ones are height and width of head that were used in cephalic index determination by a number of earlier workers. Laeeque *et al* (2013) observed an important role of head circumference and biparietal diameter of skull for determination of gender.[5]

Canthal dimensions are another important anthropometric data of significance in forensic anthropology. It is known that in a given individual, canthal values vary with age and tend to become constant in the mid to late twenties.[6] Oladipo *et al* (2013)[7], Osunwoke *et al* (2012)[8], Esomonu *et al* (2012)[9] and George and Bhat (2010)[10] in their studies have successfully shown gender differention by means of inner canthal width.

Patel *et al* (2011) have also highlighted the significance of inter-alar width in sex differentiation while studying the relationship between inter-canine width, inner canthal distance, and inter-alar width.[11]

Sex determination using dental features is primarily based on the comparison of tooth dimensions i.e. odontometrics in males and females.[4] Mesiodistal diameter of mandibular and maxillary canines provides evidence of sex determination due to dimorphism.[2,12,13] Moreover, few studies in literature also suggest the role of combined mesiodistal width of maxillary anterior teeth in sex determination.[14]

Stature is the height of a person in an upright posture and in forensic identification of unknown human remains, stature estimation is also a preliminary important step. Kalia *et al* (2008) observed a significant correlation between diameter and circumference of skull and combined mesiodistal width of maxillary anterior teeth with height of an individual by means of regression analysis.[15]

Several studies have been done on sex differentiation using craniometric and odontometric data in different parts of India, however the literature is scanty for the north Indian population especially in Uttar Pradesh. This fact has inspired us to carry out a study in Uttar Pradesh population, aiming to determine sex and height based on combined mesiodistal width of maxillary anterior teeth, right and left maxillary canine width, head circumference, inner canthal distance, inter-alar width and skull diameter.

MATERIALS AND METHODS

Present study was carried out at Department of Oral Pathology & Microbiology, King George's Medical University (KGMU), Lucknow, Uttar Pradesh, India after approval from the review board and ethical committee of the university. All the patients enrolled in this study provided their written informed consent for the study.

The research was conducted as a cross sectional prospective study for the duration of 18 weeks. Out of the screened 465 patients, reported to the outpatient department at Faculty of Dental Sciences, KGMU, 180 were finally selected for the study. Males and females were equally distributed (90 each) having their age range between 18-30 years.

The inclusion criteria for the selection of participants of the study was fully erupted teeth with healthy state of gingiva and periodontium, caries free and non attrited teeth, normal overjet and overbite, absence of spacing and malalignment in the anterior teeth, and normal molar and canine relationship. In addition, the person had no history or clinical evidence of cleft palate, orthodontic treatment, orthognathic surgery, trauma or surgery of the skull and no history or clinical evidence of metabolic disorders, endocrinal disorders and developmental disorders.

After recording the demographic information like age and sex of each participant, various craniometric and odontometric measurements were obtained with the help of a non-stretchable measuring tape, a spreading caliper and a sliding digital stainless steel Vernier caliper, as suggested in the previous studies.[11,12,15,16] The measurement range of Vernier caliper was 0 to 12"(inches) or 0 to 300 mm with jaw depth of 2.40"and resolution (least caliberation) of 0.0005" or, 0.01mm and manufactured by ATICO Medical Pvt. Ltd. Ambala

(Haryana), India. The measurements were performed by one person and all values were rounded to two decimal places. The techniques of recording of different measurements can be described as:

Combined mesiodistal width of six maxillary anterior teeth (CMWMA)

The subjects were seated comfortably on the dental chair in a relaxed state in an upright position with the head resting firmly against the head rest. The greatest mesiodistal width of each of the six permanent maxillary anterior teeth (from right canine to left canine) was measured between the anatomic contact points of the tooth interproximally and measured with the caliper beaks placed occlusally along the long axis of the tooth. Later all measurements were added to derive a combined mesiodistal width.[15]

Right (RMCW) and left maxillary canine (LMCW) width

The subjects were seated comfortably on the dental chair in a relaxed state in an upright position with the head resting firmly against the head rest. The width of right and left maxillary canine was measured as greatest mesiodistal dimension of right (RMCW) and left maxillary canine (LMCW) between the approximate surfaces of the crown and measured with the caliper beaks placed occlusally along the long axis of the tooth.[12]

Head circumference (HC)

Maximal fronto-occipital circumference was measured by placing a non-stretchable plastic tape (calibrated in millimeters) just on the occipital prominence and the supraorbital ridges, while viewing the subject laterally also to ensure proper placement of the tape. In cases of males, the tape was tightly drawn to compress the hair as much as possible. In cases of females, the subjects were asked to lift their hair in occipital area and the tape was placed against the skin and not over the lumps of hair.[15]

Inner canthal distance (ICD)

The subjects were seated comfortably on the dental chair in a relaxed state in an upright position with the head resting firmly against the head rest. The ICD was measured from the medial angle of palpebral fissure of left eye to the medial angle of palpebral fissure of right eye. The distance between these two points was measured using digital Vernier caliper without the application of pressure by bringing the recording parts of the caliper just in contact with the medial angle of the palpebral fissures.[11]

Inter-alar width (IAW)

The subjects were seated comfortably on the dental chair in a relaxed state in an upright position with the head resting firmly against the head rest. The IAW was determined by using the external width of the nose at the widest point. The distance between these two points was measured using digital Vernier caliper without the application of pressure by bringing the recording parts of the caliper just in contact with the outer surface of the nose. While measuring, the patient was asked to stop breathing momentarily to avoid any change in shape of the nose.[11]

Height (H)

Height was measured as vertical distance from the vertex to the floor, using a standard anthropometer. Measurement was taken by making the subject stand erect on a horizontal resisting plane barefooted. Anthropometer was placed in straight vertical position behind the subject with head oriented in Frankfurt plane and shoulder blocks and buttocks touching the vertical limb of the instrument. The movable rod of the anthropometer was brought in contact with vertex in the midsagittal plane.[16]

Skull diameter (SD)

The skull diameter was measured by spreading caliper between glabella and external occipital protuberance.[15] Spreading caliper is made up of two curved hinged legs, used to measure thickness and distances of skull from one side to another. It is designed specifically for the cranium and its contours and ensures high accuracy in determining the measurements. The tip of one leg of caliper was placed at glabella and the tip of other leg was touched lightly at external occipital protuberance. The reading was noted on the scale attached to the legs.

All the recorded measurements were calibrated in millimetres (mm). Statistical comparisons were made between the recorded craniometric and odontometric measurements with respect to males and females. Data was also studied as ratio of different measurements in males and females. Height was then regressed against each measurement so as to derive linear regression equations for males and females based on CMWMA, RMCW, LMCW, HC, ICD, IAW and SD.

STATISTICS AND RESULTS

Statistical analysis of all the craniometric and odontometric parameters showed a statistically significant different values for males and females i.e., p value < 0.05 (Table 1). There was significant (p=0.03) difference in CMWMA between male (48.30±3.71) and female (47.15±3.17). The RMCW (male 8.13±0.67, female 7.80±0.70) and LMCW (male 8.07±0.71, female 7.79±0.60) were also significantly higher among male subjects than females. Almost similar observation was found for HC, ICD, IAW, SD and H. Out of all measurements HC, IAW, SD and H have strongly shown sexual dimorphism (p value = 0.0001) (Table 1).

Descriptive statistics for the ratios of the recorded measurements have shown significant differences for males and females, except for the ratio of HC to CMWMA and H to SD (Table 2). The ratio of SD to CMWMA was significantly (p=0.01) higher among males (0.42±0.08) than females (0.38±0.02). Similarly, the ratio of H to CMWMA was significantly (p=0.002) higher among males (3.47±0.36) when compared with females (3.33±0.28). However, the ratio of HC to SD was significantly (p=0.009) lower among males (2.86±0.05) than females (2.93±0.07). The ratio of H to HC was significantly (p=0.0001) higher among

Table 1: Descriptive statistics for the craniometric and odontometric parameters

Parameters	Male (n=90)			Female (n=90)			p-value
	Mean±sd	Min.-Max.	CV (%)	Mean±sd	Min.-Max.	CV (%)	
Combined mesiodistal distance of maxillary anterior teeth	48.30±3.71	32.50-55.00	7.68	47.15±3.17	37.60-55.60	6.71	0.03*
Right maxillary canine width	8.13±0.67	6.00-10.00	8.28	7.80±0.70	6.00-9.70	8.93	0.001*
Left maxillary canine width	8.07±0.71	6.00-10.00	8.78	7.79±0.60	6.00-9.00	6.68	0.005*
Head circumference	54.68±1.63	51.00-59.00	2.98	52.39±1.59	49.50-57.00	3.03	0.0001*
Inner canthal distance	29.82±2.64	25.00-41.00	8.84	28.64±2.14	22.50-34.50	7.46	0.001*
Inter-alar width	41.00±3.10	35.50-49.50	7.55	36.05±2.32	31.50-42.00	6.43	0.0001*
Height	166.62±7.00	151.00-181.00	4.20	156.07±5.93	145.00-180.00	3.80	0.0001*
Skull diameter	19.06±0.50	18.50-20.10	12.33	17.88±0.62	16.80-19.30	6.05	0.0001*

*Significant in mean difference

Table 2: Descriptive statistics of ratios for the craniometric and odontometric parameters

Ratio parameters	Male	Female	p-value
	Mean±sd	Mean±sd	
Head circumference to combined mesiodistal distance of maxillary anterior teeth	1.14±0.12	1.12±0.08	0.11
Skull diameter to combined mesiodistal distance of maxillary anterior teeth	0.42±0.08	0.38±0.02	0.01*
Height to combined mesiodistal distance of maxillary anterior teeth	3.47±0.36	3.33±0.28	0.002*
Head circumference to skull diameter	2.86±0.05	2.93±0.07	0.009*
Height to head circumference	3.05±0.14	2.98±0.11	0.0001*
Height to skull diameter	8.73±0.49	8.76±0.36	0.77

*Significant

males (3.05±0.14) as compared to females (2.98±0.11) (Table 2).

Regression equations of height (H) for male and female separately showed that, HC significantly predicted the H among both male (height=113.70+0.97 x HC, p=0.03) and female (height=74.78+1.55 x HC, p=0.0001). However, ICD predicted H significantly only in males. While combined data showed highly significant prediction of H in all the craniometric parameters (p= 0.0001), and significant prediction in RMCW and LMCW odontometric parameters (p< 0.005) (Table 3).

Table 3: Regression equation of height (H) for each parameter (H being dependent variable)

	c+mx, SE, p-value		
	Male	**Female**	**Combined**
Combined mesiodistal distance of maxillary anterior teeth	159.29+0.15x, 0.20, 0.45	148.34+0.26x, 0.20, 0.19	150.32+0.23x, 8.56, 0.20
Right maxillary canine width	161.57+0.62x, 1.11, 0.58	146.51+1.23x, 0.90, 0.18	139.97+2.68x, 0.87, 0.002*
Left maxillary canine width	161.54+0.63x, 1.05, 0.55	143.02+1.68x, 1.05, 0.11	1.40.13+2.68x, 0.92, 0.004*
Head circumference	113.70+0.97x, 0.45, 0.03*	74.78+1.55x, 0.36, 0.0001*	33.44+2.39x, 0.26, 0.0001*
Inner canthal distance	149.73+0.57x, 0.28,0.04*	145.58+0.37, 0.29, 0.22	132.88+0.97x, 0.24, 0.0001*
Inter-alar width	147.27+0.24x, 0.24, 0.05	146.23+0.27x, 0.27, 0.32	115.67+1.87x,0.15, 0.0001*
Skull diameter	171.55+0.28x, 5.40, 0.96	124.68+1.78x, 1.22, 0.15	83.04+4.17x, 1.12, 0.0001*

c- constant, m-beta coefficient, x-parameter, SE-standard error

As well, the correlation coefficient between H to HC for both male and female and to ICD in males (p< 0.05) and all the combined data parameters were statistically significant (p< 0.005), with coefficient ranging from 0.23 to 0.56 except for the CMWMA (Table-4).

DISCUSSION

Diverse forensic investigations have their own importance and relevance depending on the provided condition of the human remains. Sexual dimorphism refers to the systemic difference in the form (either in shape or size) between individuals of different sexes in the same species.[17] Even if, the most accurate method of sex identification is the DNA technique but in many cases it cannot be used, due to the expensive, time consuming, laborious technique of DNA isolation and need for qualified experts in DNA identification. Also, DNA concentration of teeth

Table 4: Correlation coefficient (r) between height (H) and other parameters

Parameters	r, p-value		
	Male	**Female**	**Combined**
Combined mesiodistal distance of maxillary anterior teeth	0.08, 0.45	-0.14, 0.19	0.10, 0.20
Right maxillary canine width	0.06, 0.58	0.14, 0.18	0.23,0.002*
Left maxillary canine width	0.06, 0.55	0.17, 0.11	0.21, 0.004*
Head circumference	0.26,0.03*	0.42, 0.0001*	0.56, 0.0001*
Inner canthal distance	0.21, 0.04*	0.13, 0.22	0.29,0.0001*
Inter-alar width	0.21, 0.05	0.11, 0.32	0.52, 0.0001*
Skull diameter	0.22, 0.50	0.18, 0.38	0.39, 0.0001*

extract has been found to decrease after storage of teeth in soil, this decrease exceeded 90% after being kept 6 weeks in soil.[18]

Although, sex can be assessed with highest precision using pelvic bones alone (95%) followed by the cranial bones (90%), frequently, in forensic and archaeological excavations, skull or, teeth often provide the only identification material and the methods of gender and stature determination depend on their condition.[4]

The method of using teeth and skull measurements has several advantages as the anatomical landmarks are standard, well defined, and easy to locate.[15] In addition, teeth are resistant to mechanical, chemical, physical and thermal types of destruction. Therefore, they are very important elements in the identification of skeletal remains, especially in cases when, due to the poor preservation of skeletal remains, the identification is not possible by standard methods.[4]

In the present study, the patients between the age group of 18-30 years were selected due to a variety of reasons. Cranial dimensions are age related, the dimensions being not stable in newborns because cranial length, height and width increase as growth progress, hence gender differentiation using craniometric dimensions could be achieved once the growth ceases, i.e., only at adulthood.[5,6] In addition, on the contrary to the reported study of Farkas LG (1996),[19] who revealed that the ICD of North American Caucasians subjects reached adult size by 8 years in females and 11 years in males, the canthal values tend to become constant in the mid to late twenties.[6]

Statistical analysis of all the craniometric and odontometric parameters measurements showed statistically significant different values for males and females. Out of all measurements HC, IAW, SD and H have strongly shown sexual dimorphism (p value = 0.0001) while RMCW and ICD showed significant dimorphism. In addition, the ratios of the measurements have shown significant differences for males and females (p value < 0.05), except for the ratio of HC to CMWMA and H to SD.

The outcome of this study confirms the results of the previous studies conducted by Vodanovic *et al* (2012)[4], Laeeque *et al* (2013)[5], Oladipo *et al* (2013)[7], Osunwoke *et al* (2012)[8], Esomonu *et al* (2012)[9], Parekh *et al* (2012)[12], Khangura *et al* (2011)[17] and Omar A, Azab S (2009)[18] who determined gender by different odontometric and craniometric parameters.

Estimation of height, as part of identification process has a long history in physical anthropology. When the body has been mutilated, it is common to have the extremities or head amputated from the trunk. In this situation the details about person's stature is lost and so the assessment of stature should be established with the help of other remains.[20] This can be accomplished with the help of regression analysis, developing equations for stature estimation based on other parameters.

In the present study, the derived regression equations of height (H) for male and female separately showed that, HC significantly predicted the H among both male and female (p= 0.03, 0.0001), while ICD predicted H significantly only in males. While combined data showed highly significant prediction of H in all the craniometric parameters (p= 0.0001), and significant prediction in RMCW and LMCW odontometric parameters (p< 0.005).

All the same, the correlation coefficient between H to HC for both male and female and to ICD in males (p< 0.05) and all the combined data parameters were statistically significant (p< 0.005), with coefficient ranging from 0.23 to 0.56 except for the CMWMA.

The results are consistent with the similar studies of Chiba and Terazawa (1998)[21] and Kalia *et al* (2008)[15] who found largest correlation of skull measurements and H with combined data. However, in contrast to Chiba and Terazawa, who also observed a consistently lesser correlation (but statistically significant) for all the parameters (except skull diameter) tested for females and Kalia *et al,* who found statistically non-significant correlation for both males and females when tested separately for all the parameters, we observed a statistically significant correlation between H to HC for both males and females and to ICD in males.

The difference in the findings and the uncertain results obtained from male and female data may be attributed to an extent to the small sample, non-homogenous sampling, disparity in the methods and landmarks used for skull measurements.

The findings of our study also showed that in odontometric parameters only RMCW and LMCW showed significant prediction of H in combined data, while CMWMA showed non-significant values in separate as well as in combined data and found to be unreliable in H estimation. It is similar to the study of Kalia *et al* (2008)[15] who compared the H with CMWMA and found that CMWMA alone to be unreliable in height estimation.

More studies with large sample size and different population groups are required to explore the relationship of skull and tooth size with H and further confirm the results of this research.

CONCLUSION

The present study attempted to analyse the relationship of craniometric and odontometric parameters with gender and stature of Uttar Pradesh population. According to the study, all craniometric and odontometric parameters showed sexual dimorphism between males and females. The ratios of measurements were also significantly different among males and females except for HC to CMWMA and H to SD.

Height of the person could be significantly predicted by HC in both males and females, while ICD has predicted H significantly only in males. However, the combined data showed highly significant prediction of H by all the craniometric parameters, and significant prediction by RMCW and LMCW odontometric parameters. CMWMA had no significant contribution in height estimation.

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