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# Evaluation of craniometric measurements in human skulls

Tufan Ulcay, Burcu Kamaşak
Kırşehir Ahi Evran University, School of Medicine, Department of Anatomy, Kırşehir, Turkey

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## ABSTRACT

**Aim:** We aimed to provide a source of information that could contribute to the determination of normal values in our country and to reveal possible variations by comparing our results with the literature.

**Material and Method:** Our study was carried out on 60 skulls of unknown gender and age found in the Laboratory of the Department of Anatomy. Measurements were made directly on the skull using an inelastic and soft measuring tape, Holtain Harpenden anthropometric set, and a digital sliding caliper (Mitutoyo). In our study, using direct anthropometric measurement techniques, the measurements of the head and face regions were taken by a single researcher three times and their averages were calculated. 19 anthropometric points were determined and used for 22 measurements.

**Results:** As a result of our study, the head and face data were generally lower than the literature. Apertura piriformis height (APH), orbital length (OL) and orbital width (d-ec) results were compared as left and right asymmetry percentages, respectively; it was calculated as 1.35, 0.25, 0.26. Left measurement results were found more than right side.

**Conclusion:** In our study, it was observed that the mean values of skulls in our country were generally lower than those of other studies in the literature. At the same time, we think that comparing data with different nationalities will be important in determining the structural craniometric properties for social diversity. In addition, we believe that our findings will shed light on future research.

**Keywords:** Craniometry, skull, anthropometry

## INTRODUCTION

Anthropometric studies are a scientific method for showing different measurements and observations on human and skeleton (1). Craniofacial anthropometry; it is a branch of anthropometry that includes head and face measurements in living, cadaver and radiological samples. These measurements are important data for craniofacial surgery, plastic surgery, genetic counseling and forensic applications (2).

Using anthropometric methods in clinical practice to measure changes in craniofacial structures, features that distinguish various races or ethnic groups have been discovered (3). Cephalographers investigated human head and face profiles by measuring angles or lengths of soft tissues or dry bones using two-dimensional photogrammetry or direct measurements (4,5). Craniometry, which was developed in the 19$^{th}$ century, is a method of measuring skull and facial structure. Craniometry and other anthropometric measurements enable the widely accepted theories to be re-evaluated by arguing that standing upright and brain growth occur at the same time in human development (6). Measurement of cranial bones plays an important role in the determination and classification of population history, analysis of skeletal variation (7).

In recent years, craniometric measurements have become an important tool used by opticians, anthropologists, forensic experts and reconstructive surgeons. In this context, the importance of anthropometric studies in both our health and social life is indisputable. Although craniofacial studies in humans are abundant in our country, there are few studies on craniometric analysis of skulls.

By addressing the information gap in craniometric indices of human skulls, we aimed to provide a source of information that can contribute to the determination of normal values in our country with the findings of our study.

**Corresponding Author:** Tufan Ulcay, tufanulcay@gmail.com
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## MATERIAL AND METHOD

Our research was carried out on 60 skulls of unknown gender and age found in the Laboratory of the Department of Anatomy, Faculty of Medicine, Kırşehir Ahi Evran University. Skulls, which are the fixtures of the Anatomy department, are used as educational materials in the relevant department. Measurements were made directly on the skull using an inelastic and soft measuring tape, Holtain Harpenden anthropometric set, and a digital sliding caliper (Mitutoyo). In our study, using direct anthropometric measurement techniques, the measurements of the head and face regions indicated in **Table 1** were taken by a single researcher three times and their averages were calculated. 19 anthropometric points were determined and used for 22 measurements (**Table 1, Figure 1-4**).

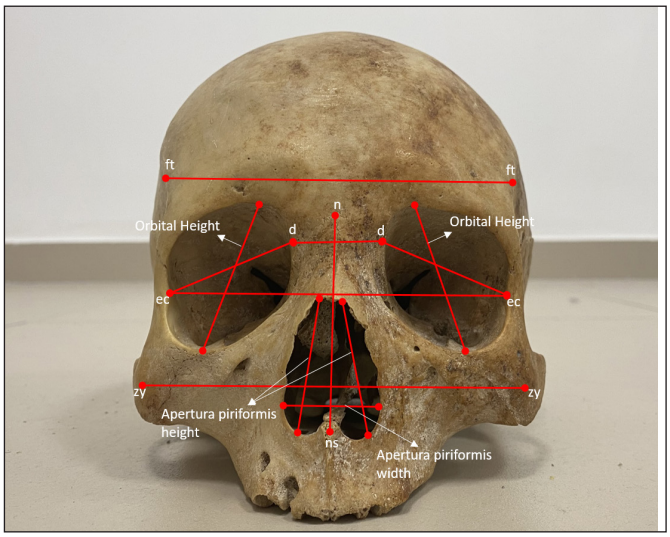


**Figure 1.** Craniometric measurements and landmarks. ft: Frontotemporale, n: Nasion, d: Dacryon, ec: Ectoconchion, zy: Zygion, ns: Nasospinale.

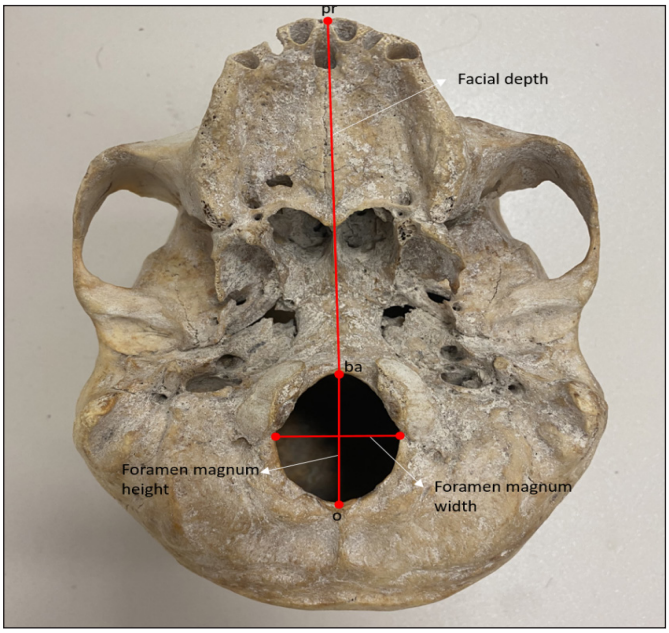


**Figure 2.** Craniometric measurements and landmarks. pr: Prosthion, ba: Basion, o: Opisthion.

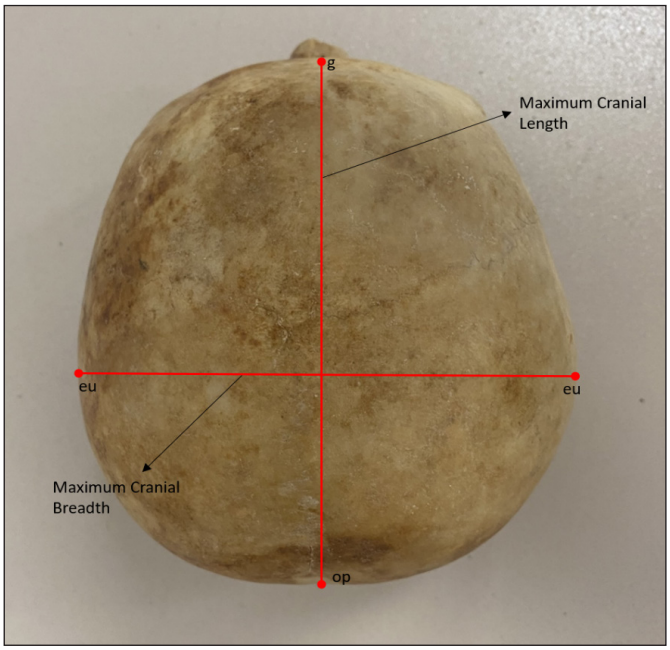


**Figure 3.** Craniometric measurements and landmarks. g: Glabella, op: Opisthocranion, eu: Euryon.

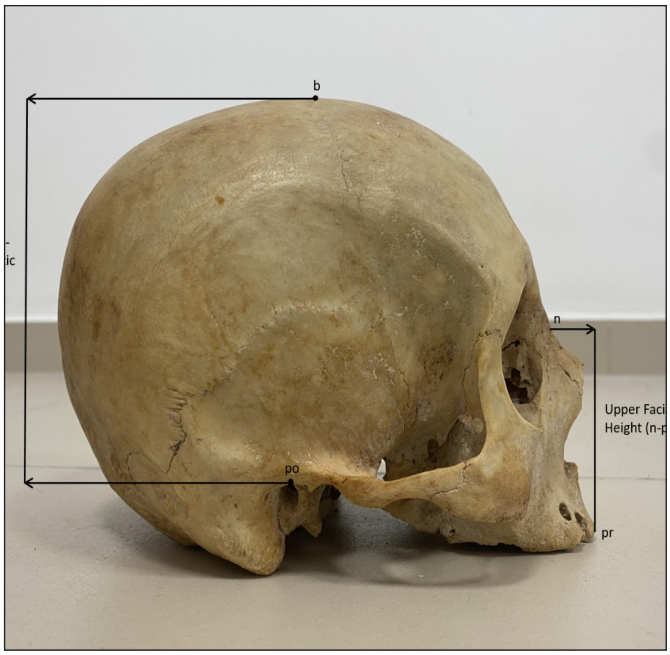


**Figure 4.** Craniometric measurements and landmarks. b: Bregma, n: Nasion, po: Porion, pr: Prosthion.

### Statistical Analysis

The data were tabulated in Microsoft Excel worksheet and the analysis of the data was performed using SPSS 22.0 package program. The results of the craniometric measurements are given as mean, standard deviation (SD), minimum and maximum values. The compatibility of right-left measurement data to normal distribution was evaluated by Histogram, Q-Q graphics and Shapiro-wilk test. Variance homogeneity was tested with the Levene test. Independent two samples t-test was used for quantitative variables in comparisons between pairs. Significance level was accepted as $p<0.05$.

**Table 1.** Craniometric measurements (2,8,9)

| No | Measurements | Abbreviation | Definition |
|---|---|---|---|
| 1 | Maximum cranial length | g-op | Length from glabella (g) in the midsagittal plane to opisthocranion (op) in the occipital bone |
| 2 | Maximum cranial width | eu-eu | The length between the most protruding points in the parietal and temporal bones on both sides of the skull |
| 3 | Maximum face width | zy-zy | Distance between the most lateral points of zygomatic (zy) arcs |
| 4 | Basion-bregma height | ba-b | Length between the projections of the basion (ba) and bregma (b) at the front edge of the foramen magnum |
| 5 | Minimum frontal width | ft-ft | The shortest distance between two frontotemporale (ft) point on either side of the forehead |
| 6 | Upper face height | n-pr | Length between nasion (n) and prosthion (pr) |
| 7 | Basi-nasal length | n-ba | Length between nasion (n) and basion (ba) |
| 8 | Facial depth | ba-pr | Length between basion (ba) and prosthion (pr) |
| 9 | Orbital width (left-right) | d-ec | Distance from Dacryon (d) to ectoconchion (ec) |
| 10 | Orbital length (left-right) | OL | Length between upper and lower orbital boundaries |
| 11 | Biorbital width | ec-ec | Distance between right and left ectoconchion (ec) points |
| 12 | Interorbital width | d-d | Distance between right and left dacryon (d) points |
| 13 | Nasal height | n-ns | Distance between nasion (n) and spina nasalis anterior (ns) |
| 14 | Apertura piriformis height (left-right) | APH | Apertura piriformis height from the distance between the lower point of the sutura nasalis and the most protruding points on either side of the spina nasalis anterior |
| 15 | Apertura piriformis width | APW | Apertura piriformis width from the furthest points in the midline in the transverse direction |
| 16 | Foramen magnum (FM) length | ba-o | Length from basion (ba) to opisthion (o) |
| 17 | Foramen magnum width | FMW | The farthest distance between the side edges of the foramen magnum |
| 18 | Horizontal circumference of the skull | g-op-g | Length of the horizontal circumference of the skull from glabella (g) to glabella (g) via opisthocranion (op) |
| 19 | Auriculo-bregmatic height | po-b | Length between porion (po) and bregma's projections |

## RESULTS

The mean±standard deviation values of craniometric measurements used in our study are shown in **Table 2** and **Table 3.**

Apertura piriformis height (APH), orbital length (OL) and orbital width (d-ec) results were compared as left and right asymmetry percentages, respectively; It was calculated as 1.35, 0.25, 0.26. Left measurement results were found more than right side. There was no statistically significant difference between the left and right measurements of these parameters showing normal distribution (p>0.05).

## DISCUSSION

In forensic and anthropological sciences, cranial analyses, whether morphognostic or morphometric, have played an important role in examining age at death, ancestry, biodistance, cranial variation and geographical relationships, cranial development, and, of course, sex differences (10). In addition, the information obtained from these analyzes can also be used in planning the surgical process to be performed in the cranial region.

Cranial length or maximum cranial length (g-op) is the distance between the glabella point and the opisthacranion point, which is the most posterior point of

**Table 2.** Cranial measurements of skulls, mean (mean)±standard deviation (SD), minimum and maximum values (mm)

| Measurements | n=60 | | |
|---|---|---|---|
| | Mean±SD | Min. | Max. |
| Glabella-opisthocranion (g-op) | 162.45 ±6.20 | 151.00 | 178.50 |
| Euryon-euryon (eu-eu) | 129.45±4.99 | 117.00 | 138.00 |
| Frontotemporale-frontotemporale (ft-ft) | 99.46±4.42 | 89.09 | 106.57 |
| Basion-bregma (ba-b) | 125.19±5.33 | 115.07 | 134.73 |
| Nasion-basion (n-ba) | 91.43±4.27 | 82.00 | 101.00 |
| Basion-prosthion (ba-pr) | 88.18±4.76 | 77.65 | 100.18 |
| Basion-opisthion (ba-o) | 35.81±7.57 | 30.17 | 90.84 |
| Foramen magnum width | 28.65±1.78 | 23.52 | 31.74 |
| Porion-bregma-porion (po-b-po) | 295.21±9.34 | 270.00 | 320.00 |
| Glabella-opisthocranion-glabella (g-op-g) | 486.43±13.27 | 460.00 | 510.00 |
| Porion-bregma (po-b) | 109.71±4.00 | 101.14 | 121.00 |

the cranium, and reaches its size in adults around the age of 10 for females and about 14 years for males (11). In our study, the maximum cranial length value was measured as 162.45±6.20 mm. This measurement average stands out as lower (approximately 10%) when compared with the findings of other studies in the literature (**Table 4**) (7,9,12-17). The maximum cranial width (eu-eu) is the distance between the most lateral points of the skull (11). In our study, the maximum cranial width findings were similar to the findings of the study conducted by Ramamoorthy et al. (14) in India, but it was found to be lower than the findings of other studies (7,9,12,13,15,16) (**Table 4**). Auriculo-bregmatic height is the height measured from the porion (po) to bregma (b) by taking the head in the Frankfurt Horizontal Plane. Tritsarol (18) reported this measurement as 128±6.9 mm, and Todd (19) reported as 115.2±0.3 mm. In our study, this height was measured as 109.71±4.00 mm. These findings of our study were found to be lower than the findings of studies in the literature.

Cranial length, cranial width and auriculo-bregmatic height measurements are linear cranial measurements and constitute the basic data in the calculation of cranial capacity. In this context, it is understood that the cranial capacities of the skulls in our study are lower than the studies in the literature.

The minimum frontal width (forehead width, ft-ft) reaches adult size at the age of 13 for females and about 15 for males (11). The minimum frontal width measurement (99.46±4.42 mm) obtained from our study was found to be higher than the results of similar studies in the literature (9,14,16,17) as indicated in **Table 4.**

The horizontal circumference of the skull is measured from glabella to glabella (g-op-g) via opisthocranion (20). The horizontal circumference of the skulls obtained in our study was measured as 486.43±13.27 mm. Ziylan et al. (12) measured this measurement as 502.2±15.8 mm in male and 496.9±19.5 mm in female. Ramamoorthy et

**Table 3.** Facial measurements of skulls, mean (mean)±standard deviation (SD), minimum and maximum values (mm)

| Measurements | n=60 | | |
|---|---|---|---|
| | Mean±SD | Min. | Max. |
| Zygion-zygion (zy-zy) | 112.07±4.91 | 96.52 | 123.71 |
| Nasion-nasospinale (n-ns) | 49.59±3.33 | 41.26 | 56.02 |
| Apertura piriformis height (APH) (left) | 36.26±3.58 | 28.33 | 42.59 |
| Apertura piriformis height (APH) (right) | 35.77±3.53 | 27.56 | 42.30 |
| Apertura piriformis width (APW) | 24.25±1.56 | 21.32 | 28.40 |
| Orbital length (OL) (left) | 36.31±2.40 | 32.04 | 41.86 |
| Orbital length (OL) (right) | 36.22±2.11 | 32.20 | 41.31 |
| Dacryon-Ectoconchion (d-ec) (left) | 38.28±1.77 | 34.33 | 43.11 |
| Dacryon-Ectoconchion (d-ec) (right) | 38.19±1.61 | 33.23 | 43.12 |
| Dacryon-dacryon (d-d) | 22.67±2.27 | 18.31 | 27.26 |
| Ectoconchion-ectoconchion (ec-ec) | 94.30±2.61 | 86.14 | 99.77 |
| Nasion-prosthion (n-pr) | 63.98±4.15 | 56.09 | 75.97 |

**Table 4.** Comparison of cranial measurements (mm) of skulls with the literature

| Author | Sex | n | g-op | eu-eu | ft-ft |
|---|---|---|---|---|---|
| Orish and Ibeachu (Nigeria) | F | 22 | 167.5±7.88 | 127.5±3.53 | - |
| | M | 78 | 180.4±8.12 | 137.2±7.95 | - |
| Mahakkanukrauh et al. (Thailand) | F | 100 | 164.02±6.76 | 138.68±5.33 | 89.43±4.25 |
| | M | 100 | 172.64±6.23 | 144.44±5.69 | 92.94±5.02 |
| Vidya et al. (India) | F | 39 | 167.7±17.3 | 132.8±14.5 | - |
| | M | 41 | 168.1±16.1 | 132.9±19.3 | - |
| Kranioti et al. (Crete) | F | 88 | 172.89±6.48 | 133.92±5.85 | 93.23±4.50 |
| | M | 90 | 181.07±6.63 | 137.64±6.63 | 96.33±4.52 |
| Ziylan et al. (Turkey) | F | 45 | 168.8±7.1 | 134.6±6.3 | - |
| | M | 40 | 170.0±8.8 | 134.8±7.3 | - |
| Padala and Khan (India) | F | 19 | 171.0±7.7 | 129.0±4.6 | - |
| | M | 31 | 179.2±6.0 | 134.0±9.6 | - |
| Ramamoorthy et al. (India) | F | 27 | 170.5±6.8 | 128.0±6.2 | 94.2±3.5 |
| | M | 43 | 178.3±8.1 | 133.0±6.2 | 96.4±4.7 |
| Steyn and Iscan (South Africa) | F | 47 | 179.0 ±5.85 | - | 93.6± 4.78 |
| | M | 44 | 187.7± 5.45 | - | 97.8±3.87 |
| Present Study (Turkey) | - | 60 | 162.45±6.20 | 129.45± 4.99 | 99.46±4.42 |

al. (14) measured the same measurement as 509.0±19.39, 492.3±14.1 mm in male and female, respectively. The result of our study was lower than the results of other studies.

The results of basion-bregma (ba-b) measurements in the skulls of Thai (9), South African whites (17), Indian (14), and Japanese (21) were higher than the same measurement result in our study (**Table 5**).

Basi-nasal length is the length between nasion (n) and basion (ba) and it was found as 91.43±4.27 mm in our study. When compared with the studies in the literature, it was found higher than female skulls and lower than male skulls (**Table 5**) (7,9,13,14,17,21), Basi-nasal length was consistent with the average values in the literature. Facial depth, the length between basion (ba) and prosthion (pr), has been measured to be lower than other studies in the literature (7,13,14,17).

The foramen magnum (FM) is an important landmark of the base of skull and is of particular interest to many fields of medicine. The dimensions of FM have clinical importance because the vital structures that pass through it may suffer compression as in cases of FM achondroplasia and FM brain herniation (22). Although the FM length obtained in our study was found higher than some studies in the literature, it was found to be lower than the measurements made by Ramamoorthy et al. (14). Although our FMW measurement is lower than the data of Ramamoorthy et al. (14) and Mahakkanukrauh et al. (9), there are also higher data in the literature (23,24) (**Table 5**).

One of the facial measurements, the maximum face width (bi-zygomatic diameter, upper face width) is the distance between the most protruding lateral points of the right and left zygomatic arches (zy-zy), and it completes its development at the age of 15 for males and 13 for females (2,25). Although the maximum face width data obtained from our study were lower compared to some studies in the literature, it was found higher than the data of Padala and Khan (9,11-14) (**Table 6**).

The interorbital width (d-d) and biorbital width (ec-ec) in the orbital region constitute important data for the harmony of the face (2). The interorbital width measurement result obtained from our study was found higher than the results of Mahakkanukrauh et al. (9) and Ramamoorthy et al. (14) and lower than the measurements of Farkas (11). Our biorbital width measurement result (94.30±2.61 mm) was found to be lower than the results of Mahakkanukrauh et al., Ziylan et al. and Ramamoorthy et al. (9,12,14) (**Table 6**).

In our study, orbital width (d-ec) was measured as left and right separately, and the left orbital width was found to be greater than the right orbital width. Orish and Ibeachu (7) and Farkas (11), in their similar study, reported that the left orbit is wider than the right orbit. In this respect, our work is similar to the work of Farkas and Orish. Although these measurement results obtained from our study were lower than the results of other studies (9,11,13,14) in the literature, they were higher than the same measurement results of women in the study of Orish and Ibeachu (7). Orbital length (OL) is the straight and widest distance between the upper and lower edges of the orbital cavity. Although these measurement results obtained from our study were higher than the results of other studies (9,13,14) in the literature, they were found lower than the same measurement results of men in the study of Orish and Ibeachu (7) (**Table 6**). The higher orbital length measurement obtained in our study than the measurements in other studies may be due to genetic and racial factors.

**Table 5.** Comparison of cranial measurements of skulls with the literature

| Author | Sex | n | ba-b | n-ba | ba-pr | ba-o | FMW |
|---|---|---|---|---|---|---|---|
| Ogawa et al. (Japan) | F | 40 | 134.0 ±3.79 | 96.3± 4.04 | - | - | - |
| | M | 73 | 142.2 ±5.47 | 103.8± 4.74 | - | - | - |
| Steyn and Iscan (South Africa) | F | 47 | 130.5±5.3 | 96.2±4.10 | 90.0±5.03 | - | - |
| | M | 44 | 136.8±4.08 | 102.4±4.48 | 95.4± 5.39 | - | - |
| Ramamoorthy et al. (India) | F | 27 | 130.2±4.69 | 98.0±5.36 | 91.8±4.81 | 36.5±2.43 | 30.7±3.0 |
| | M | 43 | 135.7±6.14 | 102.0±5.17 | 94.4±5.58 | 36.6±3.16 | 31.3±2.92 |
| Padala and Khan (India) | F | 19 | - | 97.2±5.9 | 90.3±5.1 | - | - |
| | M | 31 | - | 102.0±4.0 | 95.0±5.0 | - | - |
| Orish et al. (Nigeria) | F | 22 | - | 98.00±4.22 | 96.80±2.66 | - | - |
| | M | 78 | - | 101±5.53 | 100.5±5.95 | - | - |
| Mahakkanukrauh et al. (Thailand) | F | 100 | 132.2±4.41 | 93.07± 4.03 | - | 33.44±2.03 | 28.89±1.84 |
| | M | 100 | 138.55±4.73 | 99.64 ±3.44 | - | 35.72±2.41 | 30.63±1.81 |
| Radhakrishna et al.(India) | F | 45 | - | - | - | 31.72±2.14 | 26.59±1.64 |
| | M | 55 | - | - | - | 34.04±2.36 | 28.63±1.89 |
| Singh et al. (India) | F | 24 | - | - | - | 32.31±3.24 | 27.21± 2.99 |
| | M | 26 | - | - | - | 33.54±2.80 | 27.77±2.10 |
| Present Study (Turkey) | - | 60 | 129.45± 4.99 | 99.46±4.42 | 88.18±4.76 | 35.81±7.57 | 28.65±1.78 |

**Table 6.** Comparison of the facial measurements of skulls with the literature

| Author | Sex | n | zy-zy | d-d | ec-ec | d-ec | OL |
|---|---|---|---|---|---|---|---|
| Mahakkanukrauh et al. (Thailand) | F | 100 | 124.72±4.82 | 19.46±1.97 | 92.76±4.42 | 38.23±2.1 | 33.57±1.55 |
| | M | 100 | 133.81±3.97 | 20.14±2.26 | 98.45±3.71 | 40.49±1.82 | 34.69±1.73 |
| Farkas et al. (Canada) | - | 25 | 131.5±5.1 | 24.4±1.7 | 98.6±4.1 | 40.3±3.1 (L)<br>40.1±3.0 (R) | - |
| Ziylan et al. (Turkey) | F | 45 | 120.3±7.2 | | 99.0±6.1 | - | - |
| | M | 40 | 129.2±6.0 | | 102.9±5.1 | - | - |
| Orish and Ibeachu (Nigeria) | F | 22 | - | - | - | Left 37.8±2.3 (L)<br>Right 37.65±3.18 | Left 32.75±2.23<br>Right 32.94±2.21 |
| | M | 78 | - | - | - | Left 40.50±3.20<br>Right 40.01±3.20 | Left 36.59±5.72<br>Right 36.45±3.00 |
| Padala ve Khan (India) | F | 19 | 49.7 ±3.3 | - | - | 41.0±2.4 | 33.0±1.9 |
| | M | 31 | 54.7±5.2 | - | - | 42.0±2.8 | 31.5±3.6 |
| Ramamoorthy et al. (India) | F | 27 | 108.8±5.73 | 12.9±3.07 | 94.6±4.24 | 43.8±4.25 | 34.6±1.69 |
| | M | 43 | 113.6±6.1 | 13.4±3.11 | 97.0±4.21 | 45.1±4.9 | 34.1±2.42 |
| Present Study (Turkey) | - | 60 | 112.07±4.91 | 22.67±2.27 | 94.30±2.61 | Left 38.28±1.77<br>Right 38.19±1.61 | Left 36.31±2.40<br>Right 36.22±2.11 |

Apertura piriformis forms the bone entrance of the nasal cavity. Uygur et al. measured the height of the apertura piriformis (APH) as 35.95±3.14 mm and its width (APW) (lower part) as 23.99±2.62 mm in their study on 38 skulls (26). In the study conducted by Aksu et al. in 101 skulls, APH was measured as 33.03±4.36 mm and APW as 23.24±2.00 mm (27). Ofodile (28) measured APW in the skulls of black people from different ethnic groups; 26.50 mm in Ashanti (West Africa), 21.60 mm in Austrians, 25.20 mm in American Indians and 23.40 mm in Americans. In the same study, APH was found to be 25.80 mm, 31.40 mm, 28.60 mm and 28.20 mm, respectively. When the findings of our study regarding these measurements are compared with other studies in the literature, the APH result in our study (left: 36.26±3.58 mm, right: 35.77±3.53 mm) was found to be higher than other studies, while the APW (24.25±1.56 mm) result is similar to other studies.

Nasal height (n-ns) is the most important measurement of nose in craniometry. Orish and Ibeachu examined 100 skulls in their study and measured the nasal height as 48.48±0.78 mm in female and 55.56±3.52 mm in male (7). Mahakkanukrauh et al. (9) measured this measurement as 48.78±2.69 mm in female and 53.53±3.06 mm in male in the 200 skulls they examined. In our study, this measurement result was found to be 49.59±3.33 mm, which stood out as a lower value compared to the measurement results in the literature.

The upper face height is the distance between nasion and prosthion (n-pr) (20). The measurement of upper face height (63.98±4.15 mm) in our study was found to be lower than the results of Ziylan et al., Kranioti et al. and Steyn and Iscan (12,16,17).

When the data we obtained are compared with the literature, it is observed that the data of other studies are higher than the data obtained in our study. Genetic, racial, developmental factors, geographical location and dietary habits can be listed among the reasons for these differences. To get more accurate information about the variation of the human skull, further research should focus on comparing different analytical methods applied to the same data set.

## CONCLUSION

As a result of our study, the head and face data were generally lower than the literature. Right and left bilateral apertura piriformis height, orbital length and orbital width measurements showed right-left asymmetry, and the left side measurement results were higher than the right side.

Since it is important for radiologists, forensic anthropologists, aestheticians and neurosurgeons to know the variations of skull bones well, we think that this study will contribute to the existing knowledge about craniometric measurements and will guide the surgical interventions in this area. At the same time, we think that comparing data with different nationalities will be important in determining the structural craniometric properties for social diversity. In addition, we believe that our findings will shed light on future research.

## ETHICAL DECLARATIONS

**Ethics Committee Approval:** Skulls, which are the fixtures of the Anatomy department, are used as educational materials in the relevant department. Therefore, ethical approval is not required.

**Referee Evaluation Process:** Externally peer-reviewed.

**Conflict of Interest Statement:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

**Author Contributions:** All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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