Research Article / Araştırma Makalesi

Evaluation of Skull Morphometry in Computed Tomography Images and Calculation of the Cephalic Index

Bilgisayarlı Tomografi Görüntülerinde Kafatası Morfometrisinin Değerlendirilmesi ve Sefalik Indeks'in Hesaplanması

Sinan BAKIRCI [1], Serkan ÖNER [2]

[1]Izmir Katip Celebi University, School of Medicine, Department of Anatomy, Izmir, TÜRKİYE
[2]İzmir Bakırcay University, School of Medicine, Department of Radiology, Izmir, TÜRKİYE

Abstract

Background: The percentage distribution of skull types varies considerably between societies. Skull typing is done according to cephalic index calculation. The aim of this study is to calculate the cephalic index by making cephalometric measurements on CT images obtained from people living in our geography, and also to reveal the percentage ratios of skull types and the difference between genders.
Materials and Methods: The study was carried out on computerized tomography images obtained retrospectively of 80 healthy young adults aged 20-40 years. Measurements were made in the sagittal and coronal planes.
Results: The mean values of skull length (mm), skull width (mm), and cephalic index were 182.09±6.67, 146.60±6.30, and 80.59±4.26% in males, respectively; 173.45±6.98, 140.41±6.53 and 81.07±4.48% in females. Skull length and width were higher in males than females, and the difference was statistically significant (p<0.05). Skull type percentages in males 10% dolichocephalic, 37.5% mesocephalic, 37.5% brachycephalic, and 15% hyperbrachycephalic; it was found as 7.5% dolichocephalic, 42.5% mesocephalic, 27.5% brachycephalic, and 22.5% hyperbrachycephalic in women. The difference between the genders in terms of the cephalic index was not significant (p>0.05). The cephalic index was moderately negatively correlated with skull length and moderately positively correlated with skull width.
Conclusions: We believe that the data of our study will be useful for anatomists, anthropologists, archaeologists, forensic medicine specialists, and head surgeons. It will also be important in terms of devices and tools developed for external use for the head and face region.

Key Words: Skull types, Dolichocephaly, Brachycephaly, Mesocephali, Cephalic index, Morphometry, Anthropometry, Cephalometry

Öz.

Amaç: Kafatası tiplerinin yüzdesel dağılımı, toplumlar arasında önemli derecede farklılık gösterir. Kafatası tiplendirmesi sefalik indeks hesaplamasına göre yapılır. Bu çalışmanın amacı coğrafyamızda yaşayan insanlardan elde edilen BT görüntüleri üzerinde sefalometrik ölçümler yaparak sefalik indeksi hesaplamak, ayrıca kafatası tiplerinin yüzdesel oranlarını ve cinsiyetler arasındaki farkı ortaya koymaktır.
Materyal ve Metod: Çalışma, sağlıklı 20-40 yaş aralığında 80 genç erişkine ait, retrospektif olarak elde edilen bilgisayarlı tomografi görüntüleri üzerinde gerçekleştirildi. Ölçümler sagittal ve koronal düzlemde yapıldı.
Bulgular: Kafatası uzunluğu (mm), kafatası genişliği (mm) ve sefalik indeks ortalama değerleri, sırasıyla, erkeklerde 182,09±6,67, 146,60±6,30 ve %80,59±4,26; kadınlarda 173,45±6,98, 140,41±6,53 ve %81,07±4,48 bulundu. Kafatası uzunluğu ve genişliği erkeklerde kadınlara göre daha fazlaydı ve aradaki fark istatistiksel olarak anlamlıydı (p<0,05). Kafatası tipi yüzdeleri erkeklerde %10 dolichocephalic, %37,5 mesocephalic, %37,5 brachycephalic, %15 hyperbrachycephalic; kadınlarda %7,5 dolichocephalic, %42,5 mesocephalic, %27,5 brachycephalic, % 22,5 hyperbrachycephalic olarak bulundu. Sefaliks indeks açısından cinsiyetler arasındaki fark anlamlı değildi (p>0,05). Sefalik indeks, kafatası uzunluğu ile negatif yönde orta düzeyde, kafatası genişliği ile pozitif yönde orta düzeyde korelasyona sahipti.
Sonuç: Çalışmamızın verilerinin anatomistler, antropologlar, arkeologlar, adli tıp uzmanları, baş bölgesi cerrahları için faydalı olacağı kanaatindeyiz. Ayrıca baş ve yüz bölgesi için eksternal kullanıma yönelik geliştirilen cihaz ve aygıtlar açısından da önemli olacaktır.

Anahtar kelimeler: Kafatası tipleri, Dolikosefali, Brakisefali, Mezosefali, Sefalik indeks, Morfometri, Antropometri, Sefalometri

Corresponding Author/ Sorumlu Yazar

Dr. Sinan BAKIRCI
Izmir Katip Celebi University, School of Medicine, Department of Anatomy, Izmir, TÜRKİYE

E-mail: sinan.bakirci@ikcu.edu.tr

Received / Geliş tarihi: 17.06.2022

Accepted / Kabul tarihi: 11.08.2022

DOI: 10.35440/hutfd.1132256

Introduction

Human anatomy shows anthropometric differences depending on racial characteristics, gender, age, and many environmental factors. Based on these differences, race, gender, and age estimations are tried to be made for identification in the fields of forensic medicine and archeology. In the literature, it is possible to find studies on sex prediction based on the morphometric values of many anatomical structures such as the pelvis, sternum, sacrum, and coccyx (1,2,3). Skulls vary in shape, size, and volume. If the skull volume is between 1350-1450 cm^3, it is considered mesocephalic, if it is under 1350 cm^3, microcephalic, if it is above 1450 cm^3, it is considered macrocephalic. Europeans have macrocephalic skull volume (4). Accurate gender estimation can be achieved over 90% by logistic regression using skull metric differences (5). Skulls do not show sex discrimination in children until puberty. After puberty, differences in dimensions begin to emerge (6).

There is a possibility that the cephalic index data of a society, the percentage of cranial types, and many orthopedic and orthodontic clinical materials such as glasses and earmuffs to be produced and developed for the head and face region may affect the quantitative properties such as shape, size, and quantity. The cephalic index is obtained by multiplying the ratio of the biparietal diameter to the sagittal diameter in the skull by 100. A ratio between 75-80% indicates mesocephalic, over 80% indicates brachycephalic, and below 75% indicates dolichocephalic. Apart from these, it is possible to talk about hyperbrachycephalic and hyperdolichocephalic types (4)

In anthropometry studies, the cephalic index is often obtained by manually measuring it with a sliding-type caliper on living volunteers. During these measurements, it is necessary to feel the most protruding point on the back of the skull (4). In addition, the skull can sometimes differ in the most protruding points on the sides due to the shape differences. For this reason, there is a possibility of technical errors in manual measurements made for the cephalic index calculation. Computed tomography (CT), which can show all tissues in detail, especially bone structures, has become a frequently used method in forensic medicine and anthropology such as age, gender and race estimation. Osteometric measurements made on images brought to the three-dimensional and orthogonal plane provide realistic information without being affected by orientation errors (1-3,5).

The present study aimed to make cephalometric measurements on orthogonally plane CT images and to reveal the difference between genders in the Turkish population, considering that it wouldgive reliable results and would not allow technical errors.

Materials and Methods

The study was performed on retrospectively obtained computed tomography images of 80 healthy young adults (40 females, 40 males) aged 20-40 years (mean: 30.73±6,65). Cases with skull pathology, fracture and operation history, and images with artifacts were not included in the study. All images in DICOM format were evaluated on a personal workstation (Horos Medical Image Viewer, Version 3.3, USA). The axial plane images were analyzed with two and three dimensional reconstructions (Multi Planar Reconstruction-MPR, Maximum Intensity Projection-MIP) using a standard bone window. In order to provide standardization in three dimensions; axial images were brought to the Frankfurt horizontal plane, and sagittal, axial, and coronal CT images were adjusted to be in the midline at the same time in all three images.

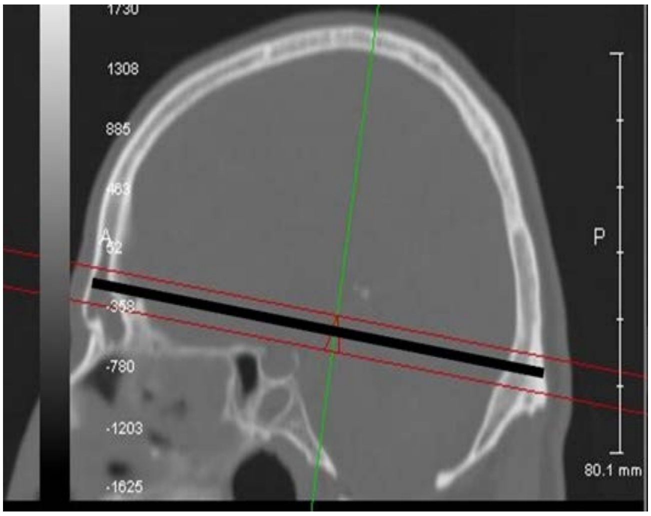

Figure 1. Measurement of skull length on sagittal CT image.

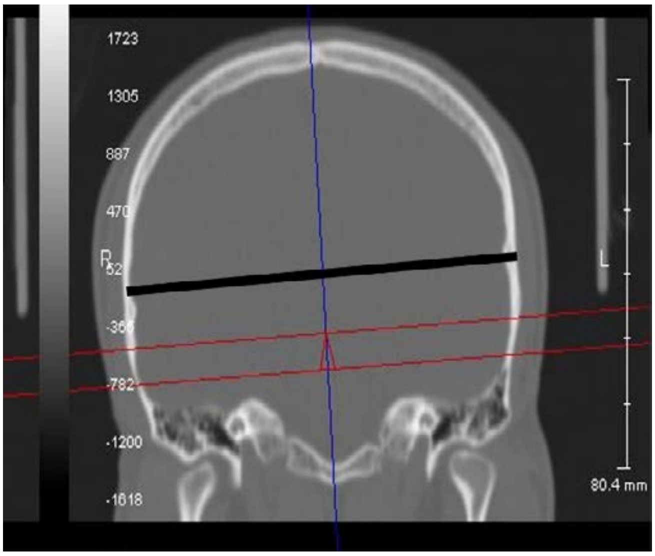

Figure 2. Measurement of skull width on coronal CT image.

Then measurements were made in the sagittal and coronal planes and recorded in millimeters. Skull length was measured from the glabella to the most posterior point of the skull (Fig. 1). The biparietal diameter was measured just above the auricle (Fig. 2).

The approval of the ethics committee of the study was given by the "Non-Invasive Clinical Research Ethics Committee of

İzmir Bakırcay University Faculty of Medicine" with the decision numbered 2022-630.

Statistical analysis

Data were evaluated with IBM SPSS 26 software. Descriptive statistical values (median, minimum, maximum, standard deviation) were obtained. The distribution of the obtained data was done with the Shapiro-Wilk test. The correlation between cephalometric values and the cephalic index was examined. Differences between the sexes were made with the independent t-test.

Results

The mean values of skull length, skull width, and cephalic index were 182.09±6.67, 146.60±6.30, and 80.59±4.26% in males, respectively; 173.45±6.98, 140.41±6.53, and 81.07±4.48% in females (Table 1, Figure 3). Skull length and width were greater in males than females, and the difference was statistically significant ($p<0.05$) (Table 2). Skull type percentages in males 10% dolichocephalic, 37.5%, mesocephalic 37.5%, brachycephalic, 15%, and hyperbrachycephalic. It was found as 7.5% dolichocephalic, 42.5% mesocephalic, 27.5% brachycephalic, and 22.5% hyperbrachycephalic in women (Table 3, Figure 4). The difference between the genders in terms of the cephalic index was not significant ($p>0.05$). The cephalic index had a high negative correlation with skull length and a high positive correlation with skull width in both genders (Table 4-6).

Table 1. Descriptive statistical values

Genders		n	Mean	Std. Deviation	Std. Error Mean
Sagittal Diameter (mm)	M	40	182.0915	6.67031	1.05467
	W	40	173.4530	6.98234	1.10401
Transverse Diameter (mm)	M	40	146.5990	6.30124	0.99631
	W	40	140.4105	6.53393	1.03311
Cephalic Index (%)	M	40	80.59	4.26	0.63
	W	40	81.07	4.48	0.75

Table 2. Statistical difference between genders

	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		Sig. (2-tailed)
			Lower	Upper	
Sagittal Diameter	8.63850	1.52681	5.59885	11.67815	0.000
Transverse Diameter	6.18850	1.43525	3.33113	9.04587	0.000
Cephalic Index	-0.00478	0.00988	-0.02444	0.01488	0.630

Table 3. Skull types and percentage rates

	Men		Women	
	(n)	(%)	(n)	(%)
Dolichocephalic	4	10	3	7.50
Mesocephalic	15	37.5	17	42.50
Brachycephalic	15	37.5	11	27.50
Hyperbrachycephalic	6	15	9	22.50
Total	40	100	40	100

Table 4. Correlation analyses at the women

		Women Cranium Lenght	Women Cranium Widht	Women Cephalic Index
Women Cranium Lenght	r	1	0.075	-.621**
n=40	p		0.644	0.000
Women Cranium Widht	r	0.075	1	.734**
n=40	p	0.644		0.000
Women Cephalic Index	r	-.621**	.734**	1
n=40	p	0.000	0.000	

Table 5. Correlation analyses at the men

		Men Cranium Lenght	Men Cranium Widht	Men Cephalic Index
Men Cranium Lenght	r	1	0.224	-.557**
n=40	p		0.165	0.000
Men Cranium Widht	r	0.224	1	.684**
n=40	p	0.165		0.000
Men Cephalic Index	r	-.557**	.684**	1
n=40	p	0.000	0.000	

Table 6. Correlation analyses at the whole group.

		Total Cranium Lenght	Total Cranium Widht	Total Cephalic Index
Total Cranium Lenght	r	1	.347**	-.527**
n=80	p		0.002	0.000
Total Cranium Widht	r	.347**	1	.613**
n=80	p	0.002		0.000
Total Cephalic Index	r	-.527**	.613**	1
n=80	p	0.000	0.000	

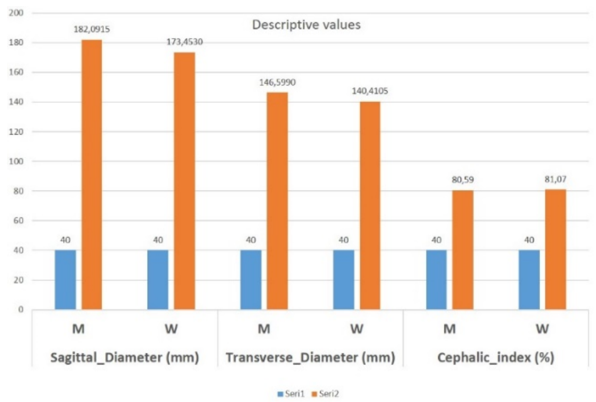

Figure 3. Cephalometric measurements by gender. M:men, W:women

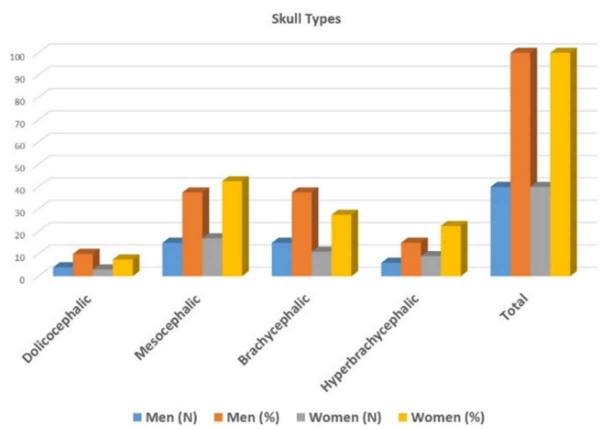

Figure 4. Number and percentage distribution of skull types by gender

Discussion

In a study carried out in Southern Odisha, India, the most common skull type in males was the mesocephalic type with 67.5%, and the dolichocephalic type was second place with 19.18%. It has been reported that the most common type in females is mesocephalic with 46.19%, brachycephalic type is the second with 31.90%, and dolichocephalic type is the third with 20% (6). There are similarities and differences between the results of this study and the results of our study. The most common head type in females was similar in both studies. However, in our study, the rate of dolichocephalic head type in women was quite low. In contrast, the hyperbrachycephalic head type is in third place. In addition, in the study of Patro et al, it was reported that there were serious differences in skull types between men and women (6). In our study, however, no significant difference was found between the genders in terms of skull types. In addition, in this study in India, the mean cephalic index values were determined as 77.28±3.22 in males and 78.38±3.77 in females ($p<0.01$). In our study, mean cephalic index values were found to be 80.59±4.26% in males and 81.07±4.48% in females. These mean values are higher than the values obtained from the study was carry out in South Odisha, and the difference between male and female genders is not significant according to the data of our study. In a study by Yagain et al. in medical students (66 males and 36 females), the cephalic index was found to be 77.92±5.2 in males. The most common skull types in males are brachycephalic (33%) and dolichocephalic (33%) types. Interestingly, the rate of dolichocephalic type is quite high when compared to our study. This result shows an important difference between the two societies. In the same study, the cephalic index was reported as 80.85±7.71 in women and the most common skull type was reported to be brachycephalic (33%). It has been reported that the least common type in women is the mesocephalic type with 9%. In our study, the incidence of the mesocephalic skull (42.5%) in women was much higher than the results of this study in India (7).

In a study carried out in Nigeria, the cephalic index was reported as 73.68±6.53 in men and 72.24±5.60 in women. The most common skull type was reported as the dolichocephalic type (66.82%). It is not possible to compare the data of this study, which seems quite different, with our study. Because this study in Nigeria was carry out on individuals aged 2-18 years. Childhood outcomes likely influenced the results of the study (8). Our study was carried out on individuals between the ages of 20-40.

In a study carried out on CT images in healthy children (0-3 years) in Poland, the mean cephalic index values were found to be 80.54±7.20 in girls and 82.22±6.87 in boys. They reported that the most common head type is mesocephalic (approximately 35%). The cephalic index mean values in the aforementioned study are close to the mean values of our study. Differently, the dominant head type in our study was the brachycephalic type (9). However, our study was carried out in the adult age group.

In a study by Zagga et al. in healthy children (0-36 months), the mean cephalic index value was found to be 79.49 ± 3.42. The most common skull type was reported as mesocephalic (31.90%) in boys and as brachycephalic (26.19%) in girls (10). The cephalic index and skull types in these children will likely change gradually with age.

In a study carried out by Hossain et al. university students in Japan with males, they examined the effect of 6 anthropometric measurements in the head and face region on the cephalic index. They reported that the skull type with the smallest mean values of bifrontal width and bizygomatic width was dolichocephalic skulls, and that these width values increased in mesocephalic and brachycephalic head types. However, the same cannot be said for the width of the face. In addition, in this study, it is not possible to make a proportional comparison between the two studies in terms of skull types, since the boundaries of skull types according to the cephalic index are different from our study (11).

Mandal et al. reported that the most common skull type in boys (53.9%) was hyperbrachycephalic in a study carried out on preschool students (3-6 years). However, the most interesting result of this study is that the cephalic index gradually decreases from the age of 2 to the age of 6 years. The incidence of hyperbrachycephali skull in boys decreased from 86.8% to 83.3%, and in girls from 87.8% to 80.5%. Therefore, although the percentage of hyperbrachycephalic head type is seen very high in boys, this rate is actually 2.7% in the 6-year-old group (12).

In a study carried out on Turkmen men (17-20 years old) in Northern Iran, it was reported that the most common skull type was brachiocephalic (50%), the least common type was dolichocephalic (8.1%). These rates are quite different from the percentage rates obtained in our study. In our study, mesocephalic and brachycephalic head types were seen at the same rate in males (both 37.5%). Since women were not included in this study carried out in Iran, it was not possible to compare our results with their results (13).

Olcay et al, in a historical review published, mentioned the existence of studies reporting that the rate of brachycephalic skull type is over 70% in our society (14). In our study, mesocephalic skull types in women and both mesocephalic and brachycephalic skull types in men are dominant. This shows that the cephalic index values of societies change over time due to many geographical and sociological multifactorial events. In addition, the measurement method differences between studies, the use of CT images in our study, may be another reason for the difference between the results.

Conclusion

We believe that the data of our study will be useful for anatomists, anthropologists, archaeologists and forensic medicine specialists. In addition, the skull type percentile rates of societies that have changed over the decades may be important in terms of devices and tools that are planned to be developed for external use in the head and face region.

Ethical Approval: *The approval of the ethics committee of the study was given by the "Non-Invasive Clinical Research Ethics Committee of İzmir Bakırcay University Faculty of Medicine" with the decision numbered 2022-630.*

Author Contributions:
Concept: S.B, S.Ö.
Literature Review: S.B, S.Ö.
Design : S.B, S.Ö.
Data acquisition: S.Ö.
Analysis and interpretation: S.B.
Writing manuscript: S.B.
Critical revision of manuscript: S.B, S.Ö.

Conflict of Interest: *The authors declare that they have no competing interest.*

Financial Disclosure: *The authors declare that they have not received any financial support for the research and writing process.*

References

1. Secgin Y, Oner Z, Turan MK, Oner S. Gender prediction with parameters obtained from pelvis computed tomography images and decision tree algorithm. Medicine Science International Medical Journal. 2021;10(2):356-361.
2. Oner Z, Turan MK, Oner S, Secgin Y, Sahin B. Sex estimation using sternum part lenghts by means of artificial neural networks. Forensic science international. 2019;301: 6-11.
3. Bakici RS, Oner Z, Oner S. The analysis of sacrum and coccyx length measured with computerized tomography images depending on sex. Egyptian Journal of Forensic Sciences. 2021; 11(1): 1-13.

4. Henry Gray. Anatomy of the Human Body. 1918. Great Books Online https://www.bartleby.com/107/47.html#note51.
5. Toy S, Secgin Y, Oner Z, Turan MK, Oner S, Senol D. A study on sex estimation by using machine learning algorithms with parameters obtained from computerized tomography images of the cranium. Scientific Reports. 2022; 12(1), 1-11.
6. Patro S, Sahu R, Rath S. Study of cephalic index in Southern Odisha population. IOSR J Dent Med Sci. 2014;13(1):41-44.
7. Yagain VK, Pai SR, Kalthur SG, Chethan P, Hemalatha I. Study of cephalic index in Indian students. Int J Morphol. 2012; 30(1): 125-9.
8. Eroje MA, Fawehinmi HB, Jaja BN, Yaakor L. Cephalic index of Ogbia tribe of Bayesla state. Int J Morphol. 2010; 28(2): 389-392.
9. Likus W, Bajor G, Gruszczyńska K, Baron J, Markowski J, Machnikowska-Sokołowska M, Lepich T. Cephalic index in the first three years of life: study of children with normal brain development based on computed tomography. The Scientific World Journal, 2014.
10. Zagga AD, Oon A H. Cranial measurements and pattern of head shapes in children (0-36 months) from Sokoto, Nigeria. Cukurova Medical Journal. 2018;43(4):908-914.
11. Hossain MG, Saw A, Alam R, Ohtsuki F, Kamarul T. Multiple regression analysis of anthropometric measurements influencing the cephalic index of male Japanese university students. Singapore Med J. 2013;54(9):516-520.
12. Mandal GC, Acharya A, Bose K. Relationship of Cephalic Index with some anthropometric variables. Human Biology Review 2016;5(3):296-308.
13. Golalipour MJ, Jahanshahi M, Haidari K. Morphological evaluation of head in Turkman males in Gorgan-North of Iran. International Journal of Morphology, 2007;25(1):99-102.
14. Neyzi O, Saka HN, Kurtoğlu S. Anthropometric studies on the Turkish population-a historical review. Journal of clinical research in pediatric endocrinology, 2013;5(1): 1.