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Anatomical and Morphometric Evaluation of the Cranial Index and Its Relevance to Clinical Syndromes

Kraniyal İndeksin Anatomik ve Morfometrik Olarak Değerlendirilmesi ve Klinik Sendromlarla İlişkisi

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Abstract

Objective: The most widely used method to define the craniofacial complex is the cranial index (CI). This index is calculated by determining the ratio between the maximum cranial width (CW) and the cranial length (CL), and is one of the clinically accepted anthropometric parameters. This study investigates the CI of Turkish dry skulls and its effects on sex, population affinity, and clinical syndromes.

Materials and Methods: One hundred adult Turkish dry skulls (57 male, 43 female) were investigated. The CI was calculated by the ratio of CL to CW and multiplied by 100 according to Martin's methods. SPSS 25 was used for statistical analysis.

Results: CI values were 88.75±1.40 mm in males and 84.90±1.13 mm in females, and differences between them were significant (p=0.045). Ultradolicocephalic and hyperdolichocephalic types were not detected. Brachiocephalic types (28%) were more frequent in females than in males, whereas ultra-brachycephalic types (33%) were more frequent in males (p<0.05). The most frequent type in Turkish dry skulls was brachycephalic (26%) and ultrabrachycephalic (26%), followed by the hyperbrachycephalic (22%), mesocephalic (21%), and dolichocephalic types (5%).

Conclusion: It can be said that the brachiocephalic type is a more frequent type in Turkish adult dry skulls. The differences in CI and type between the sexes may be indicative of sexual dimorphism. Skull types can be useful in demonstrating craniofacial abnormalities or clinical syndromes.

Keywords: Cranial index, craniometry, skull, craniofacial syndrome

Öz

Amaç: Kraniyofasiyal kompleksi tanımlamak için en yaygın kullanılan yöntem kraniyal indekstir (Cİ). Bu indeks maksimum kafatası genişliği (CW) ile maksimum kafatası uzunluğu (CL) arasındaki oran belirlenerek hesaplanır ve klinik olarak kabul edilen antropometrik parametrelerden biridir. Bu çalışma, Türk kuru kafataslarının Cİ'sini ve bunun cinsiyet, popülasyon yakınlığı ve klinik sendromlar üzerindeki etkilerini araştırmayı amaçlamaktadır.

Gereç ve Yöntemler: Yüz adet yetişkin Türk kuru kafatası (57 erkek, 43 kadın) incelendi. Cİ, CL'nin CW'ye oranıyla hesaplandı ve Martin'in yöntemine göre 100 ile çarpıldı. İstatistiksel analiz için SPSS 25 kullanıldı.

Bulgular: Cİ değerleri erkeklerde 88,75±1,40 mm, kadınlarda 84,90±1,13 mm ve aralarındaki farklılık anlamlı bulundu (p=0,045). Ultradolikosefalik ve hiperdolikosefalik tipler tespit edilmedi. Brakiosefalik tipler (%28) kadınlarda erkeklere göre daha sık görülürken, ultra-brakisefalik tipler (%33) erkeklerde daha sıktı (p<0,05). Türk kuru kafataslarında en sık görülen tip brakisefalik (%26) ve ultra brakisefalik (%26) olup, bunu hiperbrakisefalik (%22), mezosefalik (%21) ve dolikosefalik tipler (%5) izlemiştir.

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Sonuç: Çalışmamızın parametreleri ile brakiyosefalik tipin Türk erişkin kuru kafataslarında daha sık görülen bir tip olduğu söylenebilir. Cinsiyetler arasındaki Cİ ve tip farklılıkları, cinsiyet dimorfizminin bir göstergesi olabilir. Kafatası tipleri, kraniyofasiyal anormallikleri veya klinik sendromları göstermekte faydalı olabilir.

Anahtar Kelimeler: Kraniyal indeks, kraniyometri, kafatası, kraniyofasiyal sendrom

Introduction

Anders Retzius (1796-1860), developed the cephalic index, which was initially applied in physical anthropology to categorize prehistoric remains discovered in Europe (1). The cranial index (CI) is the term used by Retzius to describe his measurements when applied to dried skulls (2). Numerous variables affect the shape, size, density, and positioning of the skull and its components. Acquired diseases, posttraumatic abnormalities, neoplasia, deformations, or sutural synostosis can all be signs of a malformed skull (3). Osteopetrosis and frontometaphyseal dysplasia are skeletal dysplasias that can result in increased calvarial density, whereas hypophosphatasia and osteogenesis imperfecta can result in decreased calvarial density. The calvarial density that is diffusely diminished or elevated is typically linked to a process that affects the entire skeleton. Therefore, other features are required for accurate differentiation between these dysplasias (4).

CI is one of the most crucial factors in determining sexual dimorphism and population affinity (5). A wide range of parameters is used to determine CI, depending on age, sex, environment, ethnicity, and methodology (5). Positional plagiocephaly or sutural synostosis are the leading causes of skull malformation. The closure may not always cover the depth of the suture; therefore, the length of the sutures must be considered (4). CI must be standardized across all disciplines of expertise to improve researcher communication and enable accurate comparisons between studies (6).

Several methods have been used to investigate the form of the skull, each with its benefits and drawbacks (5). A method of systematic investigation was performed by photographing the skull in several regular planes. This had certain benefits, such as the capacity to see the landmarks of the skull in great detail. However, this approach has certain drawbacks in the form of distortions of near and far aspects of an object (5). Martin's method, which involved distributing caliper and steel tapes to establish the dry skull form, was the most commonly applied way of measuring skulls (7). These techniques and databases for craniofacial measurements have been used in several disciplines (8).

The CIs are thought of as clinical anthropometric indicators utilized in the examination of cranial anomalies (8). Therefore clinicians may change their course of action to determine whether there are any craniofacial anomalies (5). It could help forensic anthropologists classify human skulls, which can be crucial for identifying unknown skeletal remains (8). The current research aims to examine the CI in Turkish adult dry skulls and its effects on sex, population affinity, and certain clinical disorders.

Materials and Methods

In this study, 100 adult dry skulls were used. Skulls were obtained from the osteological collection of the Department of Anatomy, Akdeniz University. It was approved by the ethics committee of Akdeniz University on 26 August 2020 with protocol number 597. Twenty-one skulls with fractures, abnormalities, and pathological lesions were excluded from the study. Skull length and width measured by Digital Microcaliper. The maximum cranial length (CL) and breadth were measured according to Martin's method (7). CI is defined as the ratio of cranial width (CW) (maximum transverse diameter between two fixed points) to the CL (greatest anteroposterior diameter and the distance between the glabella and inion) and multiplied by 100 (9). To achieve intraobserver precision, three widely used precision estimates were calculated: the technical error of measurement (TEM), the relative TEM, and the coefficient of reliability (R) (10-13).

Statistical Analysis

The data were analyzed by SPSS 25 (IBM SPSS software, USA). Values are presented as mean ± standard deviation. Comparisons between the sexes were analyzed by Student's t-test. For all statistical comparisons, $p<0.05$ was assumed to indicate statistical significance.

Results

R values of the variables were near 1, indicating that most of the variables' variance was caused by other than measurement error. These findings imply that the measurement's intra-observer accuracy was acceptable. The skull types were classified according to the previous classification system described by Williams et al. (9). The detected types were presented in Figure 1.

The maximum CL and CW were 157.13 mm, 157.03 mm (males) and 157.12 mm,166.08 mm (females), respectively. The mean CI was 88.75±1.40 (males) and 84.90±1.13mm (females). The CI of males was more significant than the CI of females (Table 1). Significant differences were found according to the CI between the sexes (p=0.045). The mean CL was 146.53±1.38 mm in males and 148.91±1.51 mm in females. The mean CW was 129.31±1.26 mm in males and 126.14±1.65 mm in females. The most frequent type in Turkish dry skulls was brachycephalic (26%) and ultra brachycephalic (26%), followed by the hyperbrachycephalic

(22%), mesocephalic (21%), and dolichocephalic types (5%). The ultradolichocephalicphalic and hyperdolichocephalic types were not detected in both sexes. The ultra brachycephalic (33%) type was more frequent in males, while the brachycephalic (28%) type was more common in females. The ultrabrachycephalic type (33%) was followed by the brachycephalic (25%), hyperbrachycephalic (21%), mesocephalic (16%), and dolichocephalic types (5%) in males. The brachycephalic type (28%) and mesocephalic (28%) types were followed by the hyperbrachycephalic (23%), ultrabrachycephalic (16%), and dolichocephalic types (5%) in females.

Discussion

The present study revealed that adult Turkish dry skulls were brachycephalic type, which refers to a skull that is shorter than typical skulls. Females have shorter skulls when compared to males according to the CW and CI. This result is consistent with some studies conducted in Europe and Brazil. It has been reported that the mean CI in females was 71.48±5.81 and it was 69.75±4.02 in males, and the differences between them were significant. Gupta et al. (14) and Pandey et al. (15) reported that both CL and CW were more significant in males than females, indicating sexual dimorphism (Table 2). Salve et al. (16) reported that most males in the Andhra were dolichocephalic or mesocephalic, and females were mesocephalic, and the differences between sexes were significant (p=0.001). Similarly, Kumar and Nagar (2) (India), and Chaudhary et al. (17) (Nepal) reported that the difference between sexes according to the CI was significant (15). Chaudhary et al. (17) reported that CI could be an essential indicator to determine sex if the samples belong to the same population (CI: 71.48±5.81 in females and 69.75±4.02 in males) (17). Kumar and Nagar (2) found that male skulls tend to be dolichocephalic (53.33%) and mesocephalic (42.22%). The current study found significant differences in CI between sexes (p=0.045). The most frequent type was an ultrabrachycephalic type (33%), and it was followed by the brachycephalic (25%), hyperbrachycephalic (21%), mesocephalic (16%), and dolichocephalic types (5%) in males. However, the brachycephalic type (28%) and mesocephalic (28%) types were followed by the hyperbrachycephalic (23%), ultrabrachycephalic (16%) and dolichocephalic types (5%) in females. The findings of current study consistent with the previous studies and confirmed the sexual dimorphism. Therefore it can be said that the CI and type differences between the sexes may be an indicator of sexual dimorphism in Turkish dry skulls.

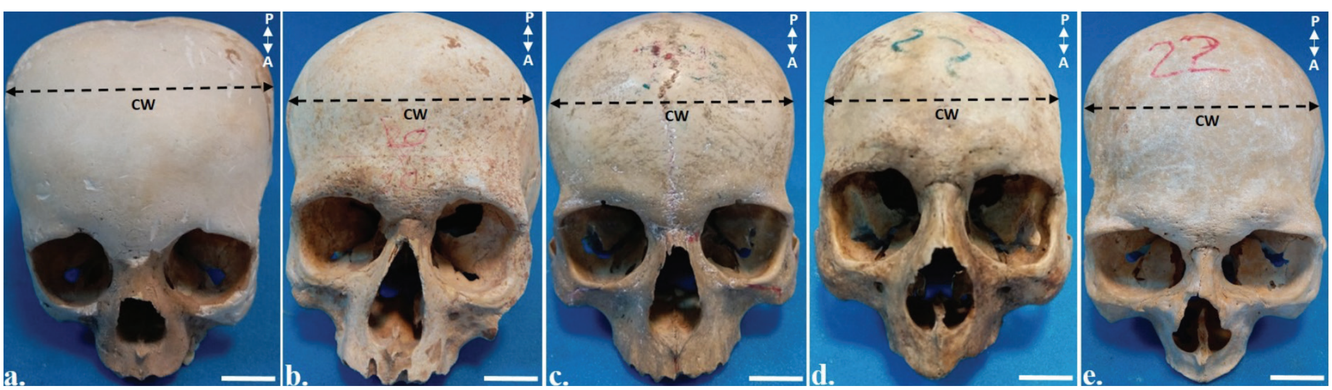

Figure 1. The five types of the skull were detected. **a.** Ultrabrachycephalic type (CW>>CL and CI ≥90 mm), **b.** Hyperbrachycephalic type (CW>CL and CI ≥85-89.9 mm) of skull has round/broad head, **c.** Brachycephalic type (CW>CL and CI=80 to 84.9 mm). The breadth greater than the length, **d.** Mesocephalic type (CL=CW and CI=75-79.9 mm). The intermediate lengths of the skull, **e.** Dolichocephalic type (CL>CW and CI=70-74.9mm). The anteroposterior diameter and length are greater than the breadth.

A: Anterior, P: Posterior, CI: Cranial index, CL: Cranial length, CW: Cranial width

Table 1. Analysis of mean cranial length (CL), cranial width (CW) and cranial index (CI) by sex

	Sex	N	Mean	Minimum	Maximum	SD	p-value
CL	Male	57	146.5342	106.77	157.13	1.38741	0.252
	Female	43	148.9175	105.74	157.12	1.51608	0.249
CW	Male	57	129.3115	97.92	157.03	1.26812	0.125
	Female	43	126.1437	96.79	166.08	1.65064	0.132
CI	Male	57	88.7530	73.86	104.37	1.40127	0.045
	Female	43	84.9052	72.96	109.37	1.13641	0.035

Independent Samples t-test. SD: Standard deviation

Table 2. Comparison of studies by years

Authors	Place	Year	N	CL (mm)	CW (mm)	CI (mean)	Cranial types
Salve et al. (16)	Andhra	2011	320	177.75±7.32 F: 172.68±4.4 M: 182.25±6.04	136.61±3.43 F:134.98±3.5 M:138.25±2.44	76.94±2.53 F: 78.2±2.33 M: 75.68±2	Dolicocephalic 42.18% Mesocephalic 54.06% Brachycephalic 3.75%
Howale et al. (18)	Maharastra	2012	75	171.1±8.9	129.8±5.4	75.49±3.95	Dolichocephalic 42.66% Mesocephalic 46.66% Brachycephalic 8% Hyperbrachycephalic 2.66%
Gupta et al. (14)	North India	2013	600	F: 177.74±8.44 M: 186.88±6.33	F: 136.19±6.13 M: 139.51±6.33	F: 76.83±5.5 M: 74.74±4.3	Dolichocephalic F: 34.67% M: 55% Mesocephalic F: 47.33% M: 32.67% Brachyphalic F: 14% M: 11.67% Hyperbrachycephalic F: 4% M :0.67%
Kumar and Nagar (2)	North India	2015	80	171.3±8.7 F: 169.1±7.4 M: 177.6±7.8	126.9±5.3 F: 126.9±6 M: 130.8±4	74.27±4.36 F: 75.22±5.15 M: 73.75±3.56	Dolicocephalic M: 53.33% F: 31.42% Mesocephalic M: 42.22% F: 62.85% Brachicephalic M: 2.22% F: 2.85% Hyperbrachicephalic M: 2.22% F: 2.85%
Pandey et al. (15)	Nepal	2016	292	F: 171±3 M: 182±6	F: 134±4 M: 138±3	F: 78.36±5.06 M: 75.82±4.43	Dolicocephalic 55.13% Mesocephalic 36.64% Brachycephalic 08.22%
Nascimento et al. (22)	Paraiba	2016	166	F: 171±7 M: 176.7±9	F: 141.9±6 M: 145±7	F: 82.9±3.2 M: 82.3±4.3	Dolichocephalic 2.41% Mesocephalic 17.47% Brachycephalic 80.12%
Madadi et al. (23)	Iran	2018	200	181.6±12.4	151.1±7.7	83.51±6.85 F: 85.87±7.33 M: 81.15±5.41	Dolichocephalic 3.5% Mesocephalic 21.5% Brachycephalic 40% Hyperbrachycephalic 35%
Woo et al. (21)	Thailand	2018	185	F: 166.85±7.76 M: 174.25± 6.52	F: 138.25±5.49 M: 142.38±5.83	F: 82.99±4.37 M: 81.81±4.23	Dolichocephalic 4.32% Mesocephalic 27.03% Brachycephalic 42.70% Hyperbrachycephalic 25.95%
Chaudhary et al. (17)	Nepal	2019	256	182.7±8.4 F: 177.1±6.0 M: 187.8±6.9	150.4±6.4 F: 147.9±5.7 M: 152.8±6.2	82.48±4.44 F: 83.62±4.08 M:81.41±4.52	Dolicocephalic 3.90% Mesocephalic 25.39% Brachycephalic 43.75% Hyperbrachycephalic 26.95%
Ay et al. (3)	India	2021	50	170.4±7.8	130.4±6.9	76.81±4.72	Hyperdolichocephalic 5.1% Dolicocephalic 13.26% Mesocephalic 20.4% Brachycephalic 11.22% Hyperbrachycephalic 1.2%
Botwe et al. (20)	Ghana	2021	300	179.1±8.6 F: 175.6±7.4 M: 182±8.5	139.4±5.4 F: 138±4.9 M: 140.5±5.6	78±13 F: 79±3.3 M: 77.3±3.6	Dolichocephalic 17.7% Mesocephalic 54.3% Brachycephalic 23.7% Hyperbrachycephalic 3% Hyperdolichocephalic 1% Ultrabrachycephalic 0.3%

Table 2. Continued							
Authors	Place	Year	N	CL (mm)	CW (mm)	CI (Mean)	Cranial types
Present	Turkey	2022	100	F: 148.9175±9.94 M: 146.5342±10.47	F: 126.1437±10.82 M: 129.3115±9.57	88.75±10.57 84.90±7.45	Dolichocephalic F: 2 (%5) M: 3 (%5) Mesocephalic F: 12 (%28) M: 9 (%16) Brachycephalic F: 12 (%28) M: 14 (%25) Hyperbrachicephalic F: 10 (%23) M: 12 (%21) Ultrabrachicephalic F: 7 (%16) M: 19 (%33)

The CI is an essential tool that might be used to identify the population affinity in various populations (2,18). Previous studies revealed that the CI among Asians differed significantly by region, such as Koreans were classified as brachiocephalic, Japanese were mesocephalic, and Siberians were mesocephalic/brachycephalic (19). African skulls were predominantly dolichocephalic, while the Europeans were categorized as brachiocephalic. However, Botwe et al. (20) indicated that the majority of Ghanaians were mesocephalic (n=163, 54.3%) and it was followed by brachycephalic (n=71; 23.7%), dolichocephalic (n=53; 17.7%), hyperbrachycephalic (n=9; 3%), hyperdolichocephalic (n=3; 1%) and ultrabrachycephalic (n=1; 3%). It has been stated that the CL and CW significantly differed from the Central and Northeast Thai and Korean females. The most frequent type was brachycephaly, followed by the mesocephalic and hyperbrachycephalic types, and the rarest type was the dolichocephalic type (21). In a study, it was revealed that the CI of females was higher than that of males in the Andhra population in India (16). It was reported that North Indian males had dolichocephalic (74.74%) and females had mesocephalic (76.83%) (14). It has been stated that the CL of Latvia and Nigeria populations were higher than North Indians (14). However, Latvia, Nigeria, Malaysians, Japanese and Sri Lankans had broader skull when compared to the North Indians, according to the CW (14). Similarly, Pandey et al. (15) reported that 68.35% of males were dolichocephalic, and 50.74% of females were mesocephalic in Nepal. However, Chaudhary et al. (17) reported that 43.75% had brachycephalic followed by hyperbrachycephalic (26.95%), mesocephalic (25.39%), and dolicocephalic (3.90%) in Nepal. It was reported that Australians and Southern Africans had dolicocephalic, Europeans and Chinese had mesocephalic, and Mongolians had brachicephalic (2). It was reported that the majority of the Brazilians had brachycephalic (80.12%) and small part of them had dolicocephalic (2.41%) (22). Madadi et al. (23) detected that the most frequent types were brachycephalic and hyperbrachycephalic in Iranians on both sexes. The parameters of our study were similar to the Europeans and Brazilians, therefore it can be said that the brachiocephalic type is more frequent in Turkish adult dry skulls. It can be due to the asymmetric growth in the displacement of the sutures, sutural synostosis of the skull to the affected side or population affinity (14).

Howale et al. (18) reported that the most frequent types were mesocephalic (46.66%) and dolichocephalic (42.66%). It has been reported that the males were predominantly dolichocephalic (55%), and the females were mesocephalic (47.33%) (14). Ay et al. (3) reported that 20.4% of South Indians were brachycephalic and 13.26% of them had mesocephalic types. It was reported that various age groups, including children, all had the same CI, and there was no absolute consistency in CI (20). The current study revealed that the most frequent type was the brachycephalic in Turkish adult dry skulls, and less common was dolicocephalic (5%) on both sexes. Ultra brachycephalic (33%) was dominated in the males and brachycephalic (28%) was dominated in females. It may be caused by several factors including osteomyelitis, alterations in fontanelles, neurofibromatosis, langerhans cell histiocytosis, skull bifidum, metastases or underlying clinical syndromes. Skull types and CI may provide valuable diagnostic data to identify local and systemic impairments. Types of the skull can be helpful for monitoring, diagnosing, and reconstruction surgery to treat craniofacial abnormalities or syndromes (20). It has been reported that dolichocephalic skulls had fewer otitis media than brachiocephaly (24). And dolichocephalic skull is more common in autosomal dominant diseases. While more hyperbrachycephalic type has been reported in Apert syndrome, more mesocephalic type has been reported in Crouzon syndrome (25). Additionally, it has been stated that CI is lower in patients with sickle cell anemia than in healthy individuals (16). A brain injury, including fetal alcohol syndrome, is usually implied by a smaller cranial vault at birth. Macrocephaly can be brought on by skeletal dysplasia or an increase in intracranial volume. It may be possible to diagnose various dysplasias with the use of skull anomalies and a variety of acquired disorders, such as trauma and abuse. Therefore, skull anomalies and their types should be evaluated to diagnose various syndromes and disorders independent of surgery.

It should be supported by radiological imaging methods. The use of 3D imaging techniques can be useful in detecting different types of skulls according to sex. Large-scale studies are required in different populations to identify the underlying clinical syndromes.

Conclusion

It can be said that the brachiocephalic type is more frequent type in Turkish adult dry skulls. The differences in CI and type between the sexes may be indicative of sexual dimorphism. Skull types can be useful in demonstrating craniofacial abnormalities or clinical syndromes.

Ethics

Ethics Committee Approval: It was approved by the Ethics Committee of Akdeniz University on 26 August 2020 with protocol number 597.

Informed Consent: Informed consent is not required.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: E.Ö., Ö.G., Concept: E.Ö., Ö.G., F.B.Y., Design: E.Ö., Ö.G., F.B.Y., Data Collection or Processing: E.Ö., Ö.G., E.S., Analysis or Interpretation: E.Ö., Ö.G., Literature Search: E.Ö., Ö.G., E.S., Writing: E.Ö., Ö.G., F.B.Y., E.S.

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