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Orbital indices in a modern Sinhalese Sri Lankan population

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Abstract

Objectives: An understanding of orbital morphology is relevant to forensic identification, craniofacial surgery, and anthropological analysis. Orbital index (OI), the relationship between the height and width of the orbit, varies between different populations of humans. This study examines modern Sinhalese Sri Lankan skulls to determine normal values for OI and explore how OI may vary with laterality and sex.

Methods: Measurements of fifty modern Sinhalese Sri Lankan skulls (origin Central Province, Sri Lanka) of known sex (34 male and 16 female) were undertaken for orbital height and width (bilaterally) using a digital caliper. OI was calculated using a standard formula ([orbital breadth / orbital height] × 100). Statistical tests analysing OI and size for both sex and laterality were performed using unpaired and paired 2-tailed t-tests ($p<0.05$), respectively.

Results: Overall mean (±standard deviation) OI was 81.29±6.14, with significant differences found between males (79.29±5.65) and females (84.39±5.59) OI. Left OI was significantly greater than right in both males (80.74±5.85 *vs.* 77.83±5.11) and females (85.47±5.70 *vs.* 83.31±5.39), indicating OI asymmetry. Individual heights and breadths of the orbits were symmetrical in both males and females.

Conclusion: Findings indicate OI asymmetry (left larger than right OI) and sexual dimorphism in this population of modern Sinhalese Sri Lankan skulls. Male orbits were microseme (OI<83) and female mesoseme (OI 83–89), an unexpected finding as Asian populations supposedly have megaseme (OI>89) orbits, therefore challenging previous assumptions on ethnic OI norms.

Keywords: measurement; orbit; orbital index; Sinhalese Sri Lankan

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Introduction

The orbits are craniofacial structures situated on either side of the sagittal plane within the skull that encroach equally upon the cranial and facial regions. Each orbit is composed of several bones arranged to form quadrilateral pyramids with their bases facing anterolaterally and slightly downward, and their apices projecting posteriomedially.[1-3] The orbits contain and protect the eyes, extra-ocular muscles and several neurovascular structures, and also allow for the accurate positioning of the visual axis,[1,4] which is essential for binocular vision. As landmark features of the skull, morphometric characterisation of the orbits is of value for anthropology,[5] tracing population origins, gaining insight into craniofacial growth due to racial and sexual differences,[6] and quantifying intraspecific variations and forensic osteology.[1,2,4,7] Moreover, comprehensive assessment and preoperative planning in areas of neurosurgery, craniofacial surgery, congenital disfigurement and trauma require specific morphometric data on orbit morphology for the safety and efficacy of clinical treatment.[8–11]

While orbit morphology has not changed significantly over recent human history, advances in surgical practice means that we are now able to utilise more detailed and specific information for the treatment of patients.[12] Thus, obtaining data elucidating intraspecific variation, such as left right symmetry (laterality), sex, and racial differences in the morphological parameters of the orbit will allow an increased depth, breadth and specificity of knowledge on orbital morphology. One well utilized parameter of orbital morphology is the orbital index (OI) which is defined as a ratio between the orbital height to its width (multiplied by 100).[13] The use of this parameter is favoured for several reasons: 1) the OI is standardized and can be measured in the living and deceased, 2) measurement is rapid and trivial, 3) OI allows for the numerical quantification of descriptive features, and 4) numerous authors have published OI data on several populations, such that the development of a race and sex specific database can possibly be considered. From previous data, three categories of OI have emerged.[14–20] Megaseme describes an OI of ≥89 and is supposedly typically seen in Mongoloid races with the exception of Inuits, while mesoseme describes an OI between 89 to 83 and is typically seen in Caucasians.[19,21] Microseme describes an OI of ≤83 and is typically seen in African races.[19,21]

The following study aims to describe normal values and variations of OI found within a contemporary population of Sinhalese Sri Lankans. The study examines and described the relationships between OI, orbital shape, laterality and sex within these skulls with a view to inform and expand current knowledge of OI and orbital morphology.

Materials and Methods

Fifty modern Sinhalese Sri Lankan skulls of known sex (34 male and 16 female, from Central Province, Sri Lanka) were measured for orbital height and width using digital calipers (Tresna 0-150 mm digital caliper with 0.03 mm accuracy; Thermo Fisher, Auckland, New Zealand) (**Figure 1**) by a single individual with ten years experience in anatomy teaching and research. Skulls with any evidence of trauma or other lesions (*e.g.* disease) that may affect measurements of the orbit were excluded from the study. Measurement methodology was determined by consensus within the research team in consultation with published methods in the field; the research team included a maxillofacial surgeon with a PhD in anatomy and twenty years research experience (author GD). OI was calculated using a standard formula - [orbital breadth / orbital height] × 100. Measurements were recorded and analyses performed using Microsoft Excel (Microsoft Corp., Albuquerque, NM, USA). Statistical tests assessing OI and size for both sex and laterality were performed using paired and unpaired 2-tailed homoscedastic t-tests ($p<0.05$), respectively. All experimental procedures were undertaken in accordance with the Declaration of Helsinki on medical ethics; experimental protocols met local institutional ethical guidelines as per similar research on human remains held by an academic institution.[22,23]

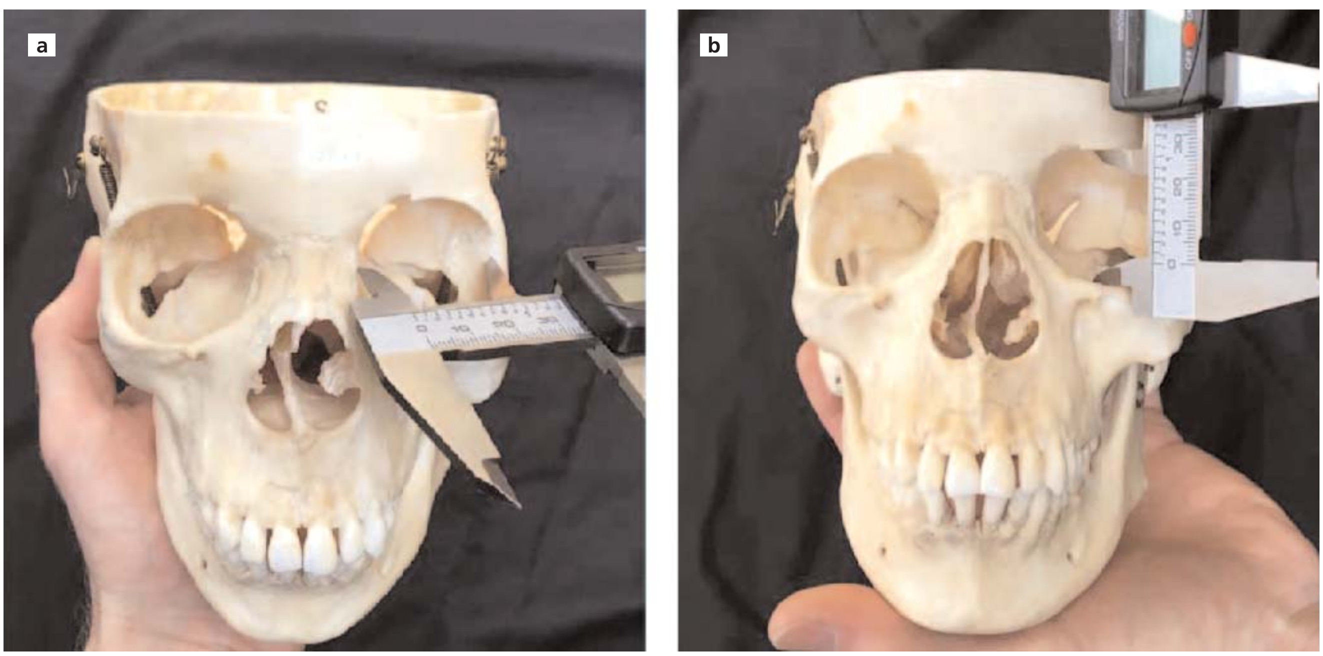

Figure 1. Demonstration of orbital measurements using a digital caliper. Measuring the width (**a**) and height (**b**) of the left orbit. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Results

Bilateral measurements from all 50 skulls were analysed. Overall mean (± standard deviation) OI for this population was 81.29±6.02, with mean male OI being significantly smaller than female OI (79.29±5.48 *vs.* 84.39±5.55; p<0.001), respectively (**Table 1**). The left OI was significantly greater than right in both males (80.74±5.85 *vs.* 77.83±5.11; p<0.0001) and females (85.47±5.70 *vs.* 83.31±5.39; p=0.032), with significant differences also seen between males and females for both the left (p=0.0043) and right (p<0.001) sides, respectively, indicating OI asymmetry. The breadths of orbits were significantly different between males and females, with orbital breadth larger in males than in females for both left (p<0.001) and right (p<0.001) orbits (**Table 1**). The measurements for heights of orbits showed no significant difference for laterality or sex.

Discussion

In this population of contemporary Sinhalese Sri Lankan skulls, the mean OI was 81.29±6.02 which places them in the microseme category. However, there were significant differences between males (79.29±5.48) and females (84.39±5.55) such that males were classified as microseme, while females as mesoseme. These differences appear to be the result of differences found in the breadths of the orbits, with male orbits being significantly wider than female orbits. Moreover, while individual orbital parameters such as height and breadth were symmetrical, orbital indices displayed left-right asymmetry. The left OI tended to be slightly smaller than the right OI in both males and females.

Orbital index

Previous studies describing OI in Asian populations found these populations typically characterized as megaseme (**Table 2**).[24,25] However, our data shows that contemporary Sinhalese Sri Lankan males are microseme whilst females fit the mesoseme category. This is discrepant in two ways. First, microseme categorisation of our skulls appears to suggest that the orbits have a more rounded morphology than other Asian populations.[1] When this is analyzed against other data from Asian population, it appears that this discrepancy is evident with most of the data available on Egyptian[2] and Indian subpopulations.[12,14,15,18,19,21,26,27] Second, Asian populations seldom display OI sexual dimorphism (**Table 2**). However, this was clearly evident within the Sinhalese population, and may reflect the selection pressures placed on the sexes within the population.

Orbital heights were consistent between males and females, and displayed left-right symmetry. The left (32.74±1.96 mm *vs.* 32.65±1.94 mm) and right (32.24±2.19 mm *vs.* 32.35±1.93 mm) orbital heights of both males and females respectively were within the range of with other neighbouring populations in India,[12,14,15,18,19,21,26,27] but smaller than Egyptian,[2] Korean,[24] andmost African populations (**Table 2**).[9,13,17,28,29] Orbital breadth was larger in males (40.63±1.92 mm, 41.47±1.94 mm; left and right sides, respectively) than females (38.27±2.1 mm, 38.91±2.39 mm; left and right sides, respectively). These values were larger than those seen in Korean populations,[24] smaller than Egyptian[2] and most African populations, but within the range of most Indian populations (**Table 2**).[12,14,15,18,19,21,26,27]

Laterality

Individually, the left and right orbital heights and breadths in males and females were not significantly different, suggesting left and right symmetry. However, when these parameters were used to derive OI, differences between the left and right sides in males and females became apparent. This indicates that individually, the differences found between the left and right side orbital height and width were not large enough to be detected by our statistical tests. Left-right asymmetry in orbital height or breadth was previously reported in Egyptian[2] and Nigerian[20] populations; morphological asymmetry is not unique to this region and was identified in other morpho-

Table 1

Data and analyses of orbital size and indices of modern Sinhalesle Sri Lankan skulls from Central Province.

	n	Left orbital height	Right orbital height	Left orbital breadth	Right orbital breadth	Left orbital index	Right orbital index
All	50	32.71±1.94	32.28±2.07	39.7±2.29	40.46±2.46	82.6±6.2	79.98±5.84
Males	34	32.74±1.96	32.24±2.19	40.63±1.9*	41.47±1.94*	80.74±5.85†	77.83±5.11*
Females	16	32.65±1.94	32.35±1.93	38.27±2.1	38.91±2.39	85.47±5.7†	83.31±5.39

*p<0.05 females vs males (unpaired 2-tailed homoscedastic t-test); †p<0.05 left vs right (paired 2-tailed homoscedastic t-test)

Table 2

Orbital indices data from this study and previously published work. Data from this study on the orbital indices of Sinhalese Sri Lankan skulls is presented for comparison with those from other ethnicities by sex and by classification.

Region	Population	Sex	Number	Orbital Index	Category	Author	Method, Source
Africa	Black Kenyan	Male	80	82.57	Microseme	Munguti et al.[30] 2013	Vernier caliper, dry skulls
		Female	70	83.48	Mesoseme		
		Mean		83.03	Mesoseme		
	Malawians	Male	70	94.35	Megaseme	Igbigbi and Ebite[13] 2010	Ruler, frontal X-ray
		Female	66	96.03	Megaseme		
		Mean		95.2	Megaseme		
	Nigerian	Male	78	89.59	Mesoseme	Orish and Ibeachu[20] 2016	Digital Vernier calipers, dry skulls
		Female	22	87.04	Mesoseme		
		Mean		88.32	Mesoseme		
	Nigerian	Male	Unknown	89.21	Megaseme	Ukoha et al.[28] 2011	Unknown
	Nigerian Binis	Male	63	78.21	Microseme	Anibor and Ighodae[17] 2013	Vernier caliper, frontal X-ray
		Female	37	75.82	Microseme		
		Mean		77	Microseme		
	Nigerian Urhobos	Male	236	78.15	Microseme	Ebeye and Otkipo[29] 2013	Not stated, living subjects
		Female	152	78.57	Microseme		
		Mean		78.36	Microseme		
Asia	Egyptian	Male	30	82.27	Microseme	Fetouh and Mandour[2] 2014	Divider and ruler, dry skulls
		Female	22	83.5	Mesoseme		
		Mean		82.89	Microseme		
	Indian	Mean	68	80.07	Microseme	Kumar and Nagar[12] 2014	Vernier calipers, dry skulls
	Indian (North)	Mean	50	82.68	Microseme	Alam et al.[18] 2016	Vernier calipers, dry skulls
	Indian (North)	Male	60	81.15	Microseme	Maharana and Agarwal[19] 2015	Manual calipers, dry skulls
		Female	40	82.16	Microseme		
		Mean		81.66	Microseme		
	Indian (North)	Mean	30	81.65	Microseme	Kaur et al.[14] 2012	Vernier calipers, dry skulls
	Indian (Central)	Mean	64	81.88	Microseme	Gosavi et al.[15] 2014	Digital Vernier calipers, dry skulls
	Indian (South)	Male	105	84.62	Mesoseme	Mekala et al.[21] 2015	Manual calipers, dry skulls
		Female	95	85.46	Mesoseme		
		Mean		85.04	Mesoseme		
	Indian (South)	Mean	50	88.41	Mesoseme	Narasinga and Pramila[27] 2015	Vernier calipers, dry skulls
	Indian (South)	Male	130	81.13	Microseme	Patil et al.[26] 2014	Vernier calipers, dry skulls
		Female	70	81.32	Microseme		
		Mean		81.23	Microseme		
	Indonesian (Batak)	Unknown	11	99.26	Megaseme	Novita[25] 2006	Not stated, frontal X-ray
	Indonesian (Flores)	Unknown	10	106.63	Megaseme	Novita[25] 2006	Not stated, frontal X-ray
	Indonesian (Klaten)	Unknown	10	102.73	Megaseme	Novita[25] 2006	Not stated, frontal X-ray
	Korean	Male	41	100	Megaseme	Hwang and Baik[24] 1999	Vernier / Marshac calipers, dry skulls
		Female		98.55	Megaseme		
		Mean		99.28	Megaseme		
	Sinhalese Sri Lankan	Male	34	79.29	Microseme	Current study	Digital Vernier calipers, dry skulls
		Female	16	84.39	Mesoseme		
		Mean		81.29	Microseme		

Orbital indices (OI) are classified in the following manner: Microseme=OI<83; Mesoseme=OI 83–89; Megaseme=OI>89.

logical features such as the jugular foramen and the superior sagittal sinus.[31] However, the majority of studies published on OI indicate left-right symmetry, though some of these observed differences were not statistically significant. Left-right orbital index asymmetry is potentially a novel finding and may be a characteristic unique to our population of skulls. Previous OI studies seldom included left-right measurements and thereby data on laterality is lacking for many other populations where OI has been studied.

Sexual dimorphism

Sexual dimorphism was evident in the orbital breadth and OI, with male skulls exhibiting a larger breadth (40.63±1.92 mm, 41.47±1.94 mm; left and right sides, respectively) and smaller OI (79.29) than female skulls (38.27±2.1 mm, 38.91±2.39 mm; left and right breadths respectively; OI=84.39±5.55). These data suggest that the females in our population of Sinhalese Sri Lankans had more rounded orbits than the males, whilst male orbits tended to be broader and more rectangular. In previous studies, OI sexual dimorphism was a feature most frequently seen in African[9,13,17,20,24] and Egyptian[2] populations, whereas sexual dimorphism in Indian and other Asian populations[12,14,15,18,19,21,24–27] were not statistically significant. The existence and extent of OI sexual dimorphism might indicate a history of significant selection pressure that was specific to our population of Sinhalese Sri Lankans.

Comparison of methods between studies

The comparison of data generated in previous studies on OI is difficult due to the diverse nature of the methodologies employed by the various authors. Methods for the studies presented in **Table 2** vary between the use of calipers (digital or manual),[12,21] measurement from X-ray,[13,25] calculations from living individuals,[29] transfer of measurementsfrom a divider to a ruler,[2] or methods not being clearly enough stated to allow reproduction of the study.[28] Reliable measurements of orbital dimensions from an X-ray is particularly problematic given the potential for error in generating a measurement of an image (X-ray) that displays a two-dimension representation of a structure that has a three-dimensional morphology (heigh, width and depth). It is also not clear whether measurements from X-rays were normalized by calibration to account for any possible image distortion. Measurements from living individuals also create difficulty for investigators looking to reliably identify orbital margins and accurately determine maximum breadth and height in each case. In addition, some sample sizes in other studies are very small and may not be representative of the populations studied.[25] Further, there are no consistently applied guidelines or criteria that studies follow which would allow confidence in the reliability of the measurement of the orbit and subsequent calculation of OI. Although the orbital measurements are recorded by taking the maximum orbital height and breadth, a standardized set of guidelines should be developed and utilized for this purpose to generate consistency of reporting and allow accurate comparison of future data. It is therefore suggested that any comparison between OI data in the presented studies (**Table 2**) be undertaken with caution given the variation in utilised methodologies.

Limitations

There is the potential for older, damaged, or well-handled skulls to be difficult to examine, especially if there is any damage around the orbital margins. None of the skulls used in this study had damage to the orbit that affected the measurement or recording. The sample size was small, in particular for the female skulls; despite this, the data do provide useful information from which to undertake a study with a larger sample size given the confirmation of variation in orbital morphology both between and within sexes. There was the potential for intra-observer variation of the recorded measurements; however, members of the research team oversaw practice of the technique to ensure consistency and repeatability, and the recorder was an anatomist who was experienced insuch measurements (*e.g.* bony measurement using digital calipers), thereby minimising the potential for overt measurement errors.

Conclusion

Modern Sinhalese Sri Lankan male orbits can be classified as microseme (OI<83) and female as mesoseme (OI=83–89), which is an unusual finding given many Asian populations are said to have megaseme (OI>89) orbits. This challenges previous suggestions regarding ethnic categorization and possible lack of ethnic variation for this morphological measure. Our findings identified the presence of left-right OI asymmetry (left larger than right OI) and sexual dimorphism in this population. This is a feature which has not been identified in neighbouring Indian populations and may be a characteristic unique to contemporary Sinhalese Sri Lankans.

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