COMPUTED TOMOGRAPHY BASED ANALYSIS OF CRANIAL PARAMETERS FOR CEPHALIC INDEX ESTABLISHMENT IN TAMIL NADU POPULATION

Dr. Chakradhar Ravipati [1], Dr. Mary Rachel Myers [2], Dr. Karthik Krishna Ramakrishnan [3]* and Dr.Vinoth Pandian [4]

[1,4] PG Resident, Department of Radio-Diagnosis, Saveetha Medical College and Hospital, Thandalam, Chennai, Tamil Nadu, India.
Email: [1]chakradharravipati5298@gmail.com, [4]vinothpandian7@gmail.com
[2] PG Resident, Department of Radio-Diagnosis, A.C.S Medical College and Hospital, Chennai, Tamil Nadu, India. Email: maryrachelmyers@gmail.com
[3] Associate Professor, Department of Radio-Diagnosis, Saveetha Medical College and Hospital, Thandalam, Chennai, Tamil Nadu, India.
*Corresponding Author Email: kkdrkr@gmail.com

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Abstract

Background: The Cephalic Index serves as a valuable anthropological instrument for dissecting racial variances within populations and uncovering sexual dimorphism. The Cephalic Index (CI) also known as the Cranial Index, represents the ratio between the maximum breadth and maximum length of the head. **Aim:** This study aimed to utilize Computed tomography (CT) scans for the anthropometric analysis of cranial parameters, establishing the Cephalic Index (CI) within the sample population belonging to Tamil Nadu, India. To discern region-specific skull types, thereby enhancing the utility of forensic medicine and anthropology in comparative and evolutionary investigations. **Materials and methods:** This cross-sectional study encompassed 500 subjects, spanning ages 5 to 93 representing both genders (261 Males and 239 Females)_conducted within the Radio-diagnosis department of Saveetha Medical College and Hospital, Tamil Nadu, India. The study utilized CT scans to precisely measure and record the Maximum Cranial Breadth (MCB) and Maximum Cranial Length (MCL) for subsequent detailed analysis. For precision assessment across various subgroups, a one-way Analysis of variance (ANOVA) was employed, ensuring meticulousness and efficacy in error evaluation. Furthermore, Multivariate logistic regression analysis was conducted to discern influential factors impacting Cephalic Index (CI) estimation, including variables such as Age, Maximum Cranial Breadth (MCB) and Maximum Cranial Length (MCL) **Result:** Within the studied cohort of 500 individuals, the 21-30 age group constituted the largest segment, comprising 23% (115 subjects). Noteworthy correlations emerged between the age groups and Cranial dimensions (MCB and MCL) through one-way ANOVA, while Cephalic Index (CI) exhibited statistical insignificance. However, robust correlations were observed between CI and variables such as Age, MCB and MCL. Additionally, a gender- based distinction was apparent with Dolichocephalic and Mesocephalic skull types more prevalent among males, while females exhibited a higher frequency of Mesocephalic skull types. **Conclusion:** Our study concludes with an average Cephalic Index (CI) of 75.9± 2.59, indicating a prevalent Mesocephalic head shape among the population in Tamil Nadu, India. This underscores the indispensable role of CT scans as a vital modality for precise assessment of cranial parameters in anthropometry. The study on cephalic index offers significant advancements for its applications in both clinical and forensic medicine. **Categories:** Radiology, Cranium, Anthropometry.

Keywords: Anthropometry, Computed Tomography, Cephalic Index, Maximum Cranial Breadth, Maximum Cranial Length, Dolichocephalic, Mesocephalic, Brachycephalic.

INTRODUCTION

The Cephalic Index (CI), also referred to as the Cranial Index, is the percentage of width to length in any skull, plays a pivotal role in discerning distinctions among human races. Initially conceptualized by a Swedish professor (1796-1860) [1]. This notion is also exploited in Forensic medicine, Plastic and Reconstructive surgery, Orthodontics

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and Clinical diagnosis (Likus, et.al., 2014; Van Lindert, 2013; Adejuwon, et.al., 2011). CI gained prominence in physical anthropology, particularly in categorizing the remains of ancient humans discovered in Europe [1].

The physical proportions of the human body are shaped by a multitude of factors, including Biology, Ecology, Geography, Gender, Race and Age [2]. The Cranial Index (CI) quantifies skull shape by multiplying its width by 100 and dividing it by its length. This index categorizes skulls broadly into three types: Dolichocephalic (<75), Mesocephalic (75 - 80) and Brachycephalic (>80). Australians and native Southern Africans typically exhibit Dolichocephalic skulls, while Chinese and Europeans lean towards Mesocephalic types. On the other hand, Mongolians and Andaman Islanders are characterized by Brachycephalic skull shapes [3].

Examining the shifts in Cranial Index (CI) across generations – Parents, Siblings and Offsprings offers insight into the genetic inheritance of certain traits [4]. In Anthropology, CI serves as a convenient metric for distinguishing individuals based on Sex, Race or even for individual identification, providing a numerical module for easy differentiation [3,4]. Cephalometric examination utilizes specialized radiography to study the intricate relationships between soft and hard tissue landmarks, providing valuable insights into the intricate dynamics of facial growth and development and in comparing variances from the established norm before treatment, monitoring throughout the treatment to assess progress, or evaluating at the treatment's conclusion to confirm the attainment of treatment objectives [5]. The lateral cephalometric radiograph is an X-ray image of the head taken with an X-ray beam directed perpendicular to the patient's sagittal plane [5,6]. The standardized head position denotes a consistently replicated head posture unique to each individual, providing a uniform approach for evaluating dentofacial morphology.

Modern advancements, notably Computed Tomography (CT), have revolutionized craniofacial imaging by enabling comprehensive visualization of the entire craniofacial structure. This technology is augmented by sophisticated computer software capable of generating capable of generating three- dimensional (3D) reconstructions from CT scans, offering life-like representations of the face and skull for precise measurements [7]. CT has emerged as a cutting edge tool in medical diagnostics, extensively employed in pre and postoperative assessments for patients with craniofacial abnormalities.

This study aimed to investigate the Cranial Index (CI) among adults in Southern India, specifically in Tamil Nadu, to identify prevalent head types and explore sexual dimorphism. The observations and insights derived from this research serve as a foundational resource for comparable cephalometric studies across diverse Communities, Castes and Races within specific geographic regions.

MATERIALS AND METHODS

This cross-sectional study was conducted at the Department of Radio-diagnosis, Saveetha Medical College and Hospital, Tamil Nadu, India involving a period of 5 months from July 7, 2023 to December 7, 2023. It involved a diverse cohort of 500 participants, ranging from ages 8 to 93 and representing both genders. The selection criteria ensured the inclusion of visibly healthy individuals without evident spinal or cranial deformities which is also confirmed by clinical examination, excluding those with congenital or acquired conditions like Scoliosis or Kyphosis. Utilizing Siemens

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Somatom definition 128 slice CT scanner. Facial bone scans were taken with following parameters : kVp 120, mAs 300-400, 5mm Collimation cross sectional thickness, 1mm Reconstruction interval .Post-processing of all images was executed on a workstation equipped with Synovia Software, allowing comprehensive analysis. The analysis of these scans was conducted by an adept and experienced Radiologists. The strictly followed ethical guidelines and obtained approval from the institutional review board before initiating the research.

The Cranial Index (CI) is computed using the following formula:

$$CI = \frac{\text{Maximum Cranial Breadth (MCB)}}{\text{Maximum Cranial Length (MCL)}} * 100$$

Referring to “ Modi’s Medical Jurisprudence and Toxicology ” classification system which identifies skulls within distinct categories;

- Those with a CI ranging from 70 -74.9 are categorized as Dolichocephalic, typical among Arborigines and pure Aryans [9,10].
- Skulls with a CI falling between 75 – 79.9 are labelled as Mesocephalic, commonly found among Europeans and Chinese [11].
- The category of Brachycephalic, denoting skulls with a CI from 80 -84.9, exemplifies short- headedness, notably seen in Mongolian race [10].

Inclusion criteria:

1. During the study period, only patients with neurological complaints referred for CT brain scans to the Department of Radiology were included and where their CT results were reported as normal.
2. Examples of reasons for imaging included Dizziness unrelated to Central nervous system disorders, fainting due to metabolic issues and individuals with bell’s palsy.

Exclusion criteria:

Patients with history of congenital intracranial anomalies, psychiatric disorders, dementia, neurodegenerative disorders, cerebral infarction, trauma, local mass lesions, prior intracranial surgery and known vascular pathology.

Statistical Analysis:

The statistical analysis was conducted using the robust Statistical Package for Social Sciences (SPSS-23, IBM Corp., Armonk, NY) software. Data representation included the meticulous presentation of frequencies as percentages and precise descriptions of mean values along with their corresponding standard deviations. To ascertain accuracy across various subgroups, the analysis employed a meticulous one-way Analysis of variance (ANOVA), designed for efficient error management. Furthermore, a comprehensive multivariate logistic regression analysis was executed to discern influential factors impacting CI estimation, encompassing variables like Age, Maximum Cranial Breadth (MCB) and Maximum Cranial Length (MCL). The chosen criterion for statisctical significance was a p- value of < 0.05.

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RESULTS

Within the cohort of 500 subjects, 115 individuals (23%) were predominantly within the 21-30 age range. The mean age for the entire study population was determined to be 49.66±10.33 years. Male subjects comprised the majority at 52.2%, compared to female subjects at 47.8% as shown in Table 1.

Table 1: Demographic Analysis :Age and Sex distribution of the studied cohort

Age Group (years)	Male (n=261)	Female (n=239)	Total (n= 500)
< 20	35 (13.4%)	30 (12.5%)	65 (13%)
21-30	60 (22.9%)	55 (23.0%)	115 (23%)
31-40	29 (11.1%)	35 (14.6%)	64 (12.8%)
41-50	25 (9.5%)	32 (13.3%)	57 (11.4%)
51-60	31 (11.8%)	27 (11.2%)	58 (11.6%)
61-70	38 (14.5%)	23 (9.6%)	61 (12.2%)
71-80	22 (8.4%)	19 (7.9%)	41 (8.2%)
>80	21 (8.0%)	18 (7.5%)	39 (7.8%)
Mean age (Mean +- SD) years	**51.67 +-10.45**	**47.68+- 10.47**	**49.66 +-10.33**

The study reported a mean Maximum Cranial Length (MCL) of 20.9±0.52 cm, a mean Maximum Cranial Breadth (MCB) of 14.4±0.29 cm and a mean Cephalic Index (CI) of 75.9± 2.59. The distribution of MCL, MCB and CI was statistically significant ($p < 0.001$) as illustrated in (Table 2).

Table 2: Diversity in Anthropometry Measures: Examining Gender -Based Differences in Maximum Cranial Length, Maximum Cranial Breadth and Cephalic Index.

Variables	Total	Male	Female	P value
Maximum Cranial Length (cm)	20.9±0.52	21.5±0.41	19.7±0.59	<0.001
Maximum Cranial Breadth (cm)	14.4±0.29	14.5± 0.32	14.7±0.31	<0.001
Cephalic Index	75.9±2.59	75.1±2.04	77.4±2.35	<0.001

Various types of skull with specific values of MCB, MCL are illustrated in (Figure 1,2 and 3).

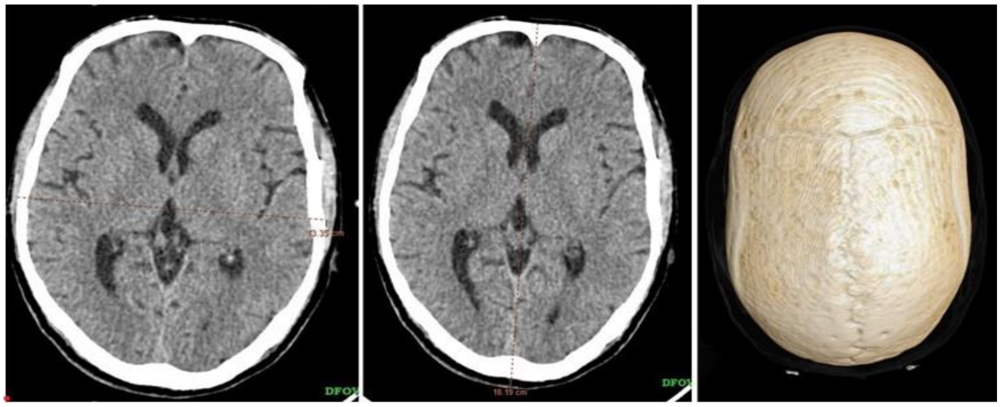

Figure 1: Images depicting Dolichocephalic skull.

(a) MCB – 13.35 cm (b) MCL – 18.19 cm (c) CI- 73.3

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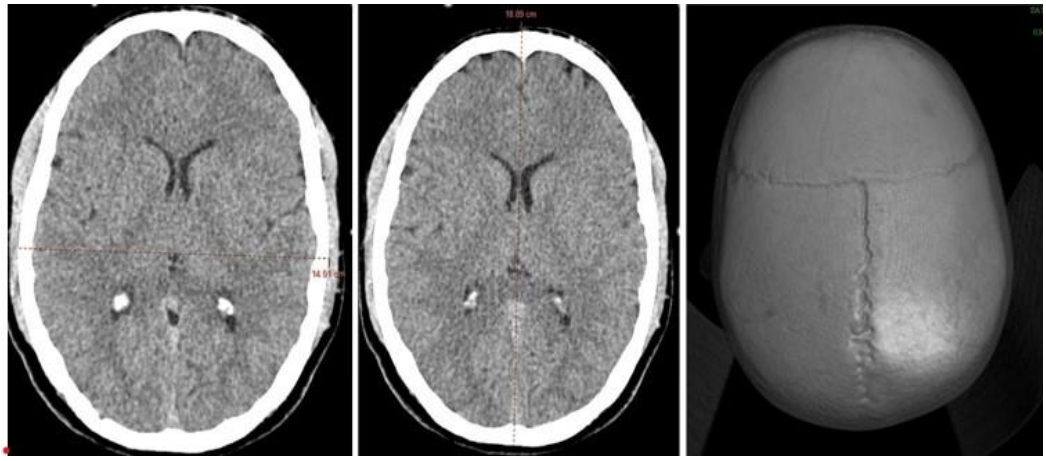

Figure 2 : Images depicting Mesocephalic skull

(a) MCB – 14.01 cm (b) MCL – 18.09 cm (c) CI- 77.4

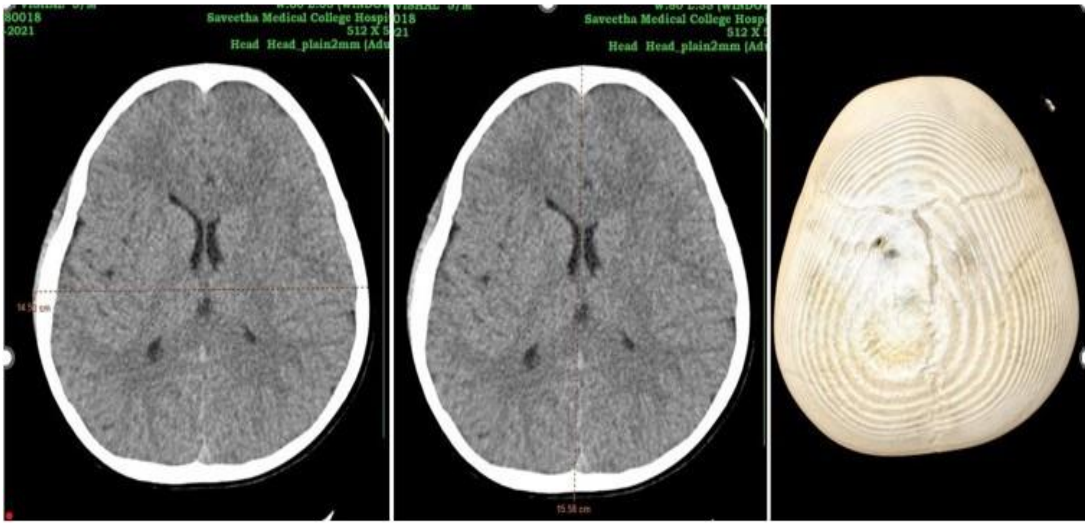

Figure 3: Images showing Brachycephalic skull

(a) MCB -14.53 cm (b) MCL- 15.58 cm (c) CI – 93.2

Dolichocephalic and Mesocephalic skull types are relatively predominant among male subjects, while Mesocephalic skull is more prevalent among females as shown in (Table 3) and (Figure 4).

Table 3: Gender- Specific categorization of subjects.

Sex	n	Dolichocephalic	Mesocephalic	Brachycephalic
Male	261	131	129	1
Female	239	90	135	14
Total	500	221	264	15

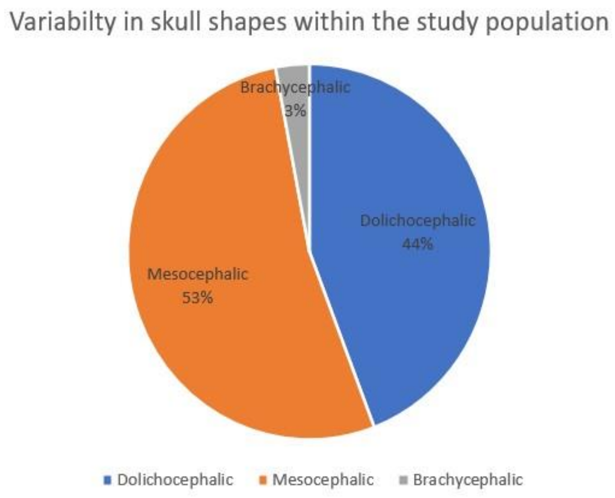

Figure 4: Variabilty in skull shapes within the study population

In our study, the predominant skull type identified was Mesocephalic accounting for 53% of the cohort population.

DISCUSSION

Craniofacial anthropometry plays a crucial role in evaluating facial trauma, identifying inherited deformities, detecting defects and diagnosing various diseases [11-13]. The necessity for indigenous data arises from the understanding that these values reflect potentially distinct shapes in craniofacial development influenced by ethnic, racial and sexual differences [14]. The Cephalic Index (CI) serves as a measurement scale for skull size, determined by multiplying width of the head by 100 and dividing the result by the maximum length of the head. This index is strategically designed as a discriminative parameter to identify variations in head growth. Deviations from the mean are assessed where the calculated index falls outside the range of ± 2SD.

It facilitates a critical assessment of heads that deviate significantly in size. Moreover, the CI indirectly reflects cranial capacity, offering an indirect measure of brain volume and the potential to predict mental ability [15].

Williams et al. (1995) documented gender and racial variations in the cranium. In a study conducted by Shah G.V. and Jadhav H.R, involving 500 medical students from Gujarat (302 males and 198 females), the mean cephalic index was reported as 80.81. Furthur analysis revealed a mean Cephalic Index of 80.42 for males and 81.20 for females, with the majority of subjects falling into the mesocephalic group. Additionally, the mean head length was found to be 18.26 cm for males and 16.5 cm for females [4]. We conducted a comprehensive cross-sectional study involving 500 subjects compared to previous studies by Singh and Purkit, where they performed a cross-sectional study with 200 subjects [16] and Paulinus et al. carried out a retrospective and prospective study with over 200 subjects [17]. Compared to these studies our study encompassed a substantial number of subjects in each gender and age group, providing a robust dataset for analysis. In this study, mean age for the entire study population was determined to be 49.66+-10.33 years. Male subjects comprised the majority at 52.2%, compared to female subjects at 47.8% (Table 1).The study reported a mean Maximum Cranial Length (MCL) of 20.9±0.52 cm, a mean Maximum

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Cranial Breadth (MCB) of 14.4±0.29 cm and a mean Cephalic Index (CI) of 75.9±2.59. In our study, the prevalent head shape was Mesocephalic, followed by Dolichocephalic. In tropical regions, people typically exhibit a longer head form (dolichocephalic), while in temperate zones, the head tends to be more rounded (mesocephalic or brachycephalic). With India's diverse climate zones, encompassing both temperate and tropical regions, our findings reinforce this trend towards Mesocephalization. Our study on Cephalic Index (CI) when compared with previous research, indicates a trend towards 'Mesocephalic' skull type, suggesting continued lateral brain growth. [18].

Comprehensive knowledge of cranial parameters, including the Cephalic index, plays a pivotal role in a multitude of critical applications within both clinical and forensic domains. This understanding not only aids healthcare professionals in accurately diagnosing and treating various medical conditions but also provides forensic experts with invaluable tools for precise identification and investigation purposes. Utilizing ultrasonography to measure fetal liver and cranium dimensions enables early prediction of complications like preeclampsia with intrauterine growth restriction (IUGR), facilitating timely interventions to reduce perinatal morbidity and mortality besides preventing growth restriction and neurological disorders in newborns [19]. The Hepatic Cranial Index (HCI), calculated as Fetal Liver Length (FLL) to Biparietal Diameter (BPD) ratio, was lower in foetus with IUGR [19]. A study by Stephens AS et al. established brain-to-liver weight ratio thresholds for IUGR, showing a positive association [20]. Lannelongue, Lane, Shillito, and Matson suggested that early intervention, via open surgeries or cranioplasty, in craniosynostosis could promote proper brain expansion and skull development, potentially preventing increased intracranial pressure [21].

The Cephalic index (CI) serves as a pivotal reference for diagnosing and treating cranial deformities, encompassing both traditional surgical methods and advanced techniques such as spring-mediated cranioplasty and cranial remodelling helmet therapy [21-23]. Cranial remodelling therapy enhances surgical outcomes and prevents regression in sagittal suture craniosynostosis. The helmet facilitates biparietal expansion, vital for achieving optimal aesthetics. Endoscopic procedures, when combined with helmet therapy, can normalize frontal morphology comparable to open surgery [24,25].

Machine learning frameworks, such as the one developed by Knoops et al., provide automated diagnosis in plastic surgery and have potential applications in neurosurgery [26]. They can aid in preoperative planning for cranial springs by utilizing information on the spring's effect on cranial index and predicting post-operative cephalic index [27]. These algorithms can also evaluate the impact of metopic severity on aesthetic outcomes following fronto-orbital advancement in metopic craniosynostosis [26]. Critical variables influencing the modification of cranial index (CI) by spring-mediated cranioplasty include maximum and total spring forces, anterior and posterior spring lengths, spring positioning relative to sutures, duration of spring placement, osteotomy sizes, and skull thickness [28]. Post-operative cephalic index prediction relies on an average template derived from statistical shape modelling, validated through finite element analyses. These analyses simulate skull displacements, confirming predictions made by the machine learning algorithm [29].

Study of CI in specific age group is crucial to decide the candidate for specific helmet therapy as in the Korean population, age-related changes in cranial index were noted, peaking at 4–6 months and gradually declining by 3–4 years with minor variations noted upto 7 years of age [30]. Complete fusion of the anterior one-third of the sagittal suture correlated with higher Cranial Index (CI) values. Yet, the total degree of sagittal suture fusion showed no predictive association with CI or head shape in any analysis [31].

The cephalic index can also be derived using interdental measurements, leveraging the preserved integrity of the maxillary dentition in the skull. This establishes it as a reliable anatomical reference for human identification. Consequently, mean cranial and facial indices were calculated and correlated with interdental measurements, particularly focusing on Intercanine width. The cephalic index was derived using the equation: 78.4389–0.0560 × Inter-Canine width., Thus aiding forensic artists in reconstructing highly decomposed faces, particularly in mass disaster scenarios [32].

Continued research on the cephalic index has refined the understanding, leading to the identification of the modified Cephalic index. Lisa M, et.al, identified level 7 (superior to eurions) as the most responsive cranial height for measuring cephalic index (CI) following cranial remodelling therapy, surpassing the traditional level 3(level of glabella) measurement [33].

The implementation of the adjusted CI (aCI) by Nicholas, et.al, revealed greater regression compared to the traditional CI, as it incorporates the ideal euryon location in biparietal diameter measurement which helps in the modification of the helmet design [24].

Phelan et al., research influenced by the 'Back to Sleep' campaign and encompassing a diverse population sample, has led to the establishment of updated cephalic index values for infants and children [34].The mean cephalic index for healthy children aged 0–1 month and 4–6 months was 0.83 and 0.86, respectively, surpassing the values reported by Farkus et al. (0.737 for males and 0.733 for females) for children under 6 months.

Consequently, necessitating a revision of the definition of plagiocephaly for the application of helmet orthosis [34,35]. Longitudinal studies on cephalic index hold promise for unveiling invaluable insights into distinct craniofacial characteristics, alongside the potential for introducing novel methods of identifying cephalic index.

CONCLUSION

The Cephalic Index (CI) serves as a valuable and essential tool for evaluating skull shape in both adults and children, particularly for pre- and postoperative correction of skull deformations. Our observations in the Tamil Nadu, South Indian population reveals Mesocephalic as the predominant skull shape. Sexual dimorphism parameters in cranial dimensions have been thoroughly examined and established in the Southern Indian population particularly belonging to Tamil Nadu. A comprehensive understanding of cranial parameters and the cranial index is crucial for assessing Age, Gender and Racial differences, with significant implications for both Clinical and Forensic applications.

Abbrevations:

CT – Computed Tomography

CI – Cephalic Index

MCB – Maximum Cranial Breadth

MCL- Maximum Cranial Length

ANOVA -Analysis of Variance

SPSS- Statistical Package for Social Sciences

SD – Standard Deviation.

IUGR- Intrauterine Growth Restriction

HCI- Hepatic Cranial Index

FLL- Fetal Liver Length

BPD- Biparietal Diameter

Consent for publication

We, the undersigned authors of the research paper titled: “Computed Tomography based analysis of Cranial parameters for Cephalic Index establishment in Tamil Nadu Population” hereby provide our consent for the publication of this manuscript. We affirm that all authors have thoroughly reviewed and endorsed the final version of the manuscript and consent to its submission for peer review and eventual publication.

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Disclosure Statement

The authors declare no conflicts of interest.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising the paper, and have collectively agreed to take responsibility for all aspects of this work.

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Accompanying Sheet

What is already known about this topic?

Craniofacial anthropometry is pivotal for assessing facial trauma and discerning inherited deformities. The Cephalic Index (CI) functions as a crucial metric for quantifying skull size and to distinguish human traits among different populations.

What question did this study address?

This study identified the predominant skull type within the Tamil Nadu population by analyzing the cephalic index through Computed Tomography (CT) scans which holds potential implications for cranial remodelling techniques and forensic applications

What this study adds?

This study contributes by documenting craniofacial traits and sexual differences with respect to the Cephalic Index within the Tamil Nadu population by utilizing Computed Tomography. The identification of the predominant head shape as Mesocephalic provides valuable insights into craniofacial morphology within this population, indicating ongoing lateral brain growth. These findings have significant implications for cranial remodelling, encompassing both traditional methods and advanced techniques leveraging artificial intelligence.

Suggestions for further development

1. Future research could expand upon this study by including a larger and more diverse sample size, covering a wider age range and including individuals from different regions within Tamil Nadu.
2. Longitudinal studies could also be conducted to track changes in craniofacial morphology over time within the Tamil population.
3. Moreover, comparative studies with other populations could provide valuable insights into the unique craniofacial characteristics and contribute to the broader understanding of human craniofacial variation. Such knowledge holds potential applications in clinical practice, forensic investigations, and evolutionary studies.
4. More research on cephalic index studies can help us learn more about different facial shapes and may bring new ways to measure them