Exploring Morphometry of Human Faces: A review of Anthropometric parameters

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Abstract

Anthropometry is the scientific study of methods and techniques used to measure the human body. It has numerous applications in studying the variation of human physical features over the years, the field of forensic investigations, and palaeoanthropology. Facial anthropometry, a subset of this field, focuses on studying facial features. It helps identify race, ethnicity, sex, and age. This study examines various indices, including the nasal, cephalic, facial, and orbital indexes. The nasal index aids in classifying different types of noses. The cephalic index studies different head types, while the facial index expresses wideness of a person's face is relative to its length. The orbital index measures the orbital cavity using the ratio of height of the orbits to its width, multiplied by 100. These anthropometric features are essential for studying the human face and are invaluable to researchers and scientists in analyzing human history and development.

Keywords- Human evolution, Human Face, Anthropology, Cephalic Index, Facial Index, Orbital Index, Nasal Index

Introduction

The study of individuals and their civilizations across various facets, including origin, development, biological features, and behavior, is considered anthropology. It encompasses all aspects related to humans. The society in which individuals live, their culture, norms, social structure, organization, religion, language, and other components are part of human society. The scientific methodologies and procedures involved in studying the human body fall under anthropometry. Anthropometry focuses on measuring the physical properties of humans, covering all dimensions of the body. The accuracy and affordability of anthropometric technology contribute to its prominence. With a high degree of precision, it is used to track growth and development trends for therapeutic applications (Chandra et al., 2012). These parameters of the human body heavily rely on studying psychology, human geography, anthropology, and epidemiology, providing systematic knowledge about both extinct and living populations. Anthropometry techniques also allow us to learn about our ancestors, their origins, and development. It helps evaluate racial differences and racial types, proving valuable in studying palaeoanthropology, which includes the study of human evolution and origin through fossil remains.

Facial anthropometry studies all facial features, including the head, nose, eyes, face, lips, and ears. Each of these features has a unique index upon which it is calculated. It has become a critical approach and a significant tool in forensic investigations and reconstructive procedures. Cephalometry, used by forensic professionals and anthropologists, helps recreate facial features of disputed identities by identifying ethnic and sexual variations and comparing differences among parents, children, and siblings (Shah & Jadhav, 2004). These methodologies provide insights into the history of humans and their ancestors. Race, sex, and ethnicity have played significant roles throughout human history and can be studied and utilized in forensic investigations. The nose, situated at the centre of the face, defines a person’s beauty. Climate and geography influence the shape and size of the nose, which varies from person to person. The nasal index, used to classify people based on their noses, is calculated by measuring the ratio of nose width to length and multiplying it by 100. A higher nasal index denotes a wider, flatter nose, while a lower nasal index indicates a taller, narrower nose. Additionally, it examines how genetic and environmental factors influence the evolution of noses in various populations.

Cephalometry is a method for integrating the numerous anatomical relationships of the human head into a mathematical framework (Mandal et al., 2016). The scientific study of the human head is conducted using the cephalic index, an essential metric for determining the size and structure of an individual. It is computed by dividing the width of the head by the height of the head and multiplying the result by 100. The cephalic index aids in research on the evolution of the human species and helps determine racial characteristics in fields such as anthropology and biometry. A complex interplay between genetic and environmental factors has been identified as causing variations in cephalic indices both within and between communities (Kasai et al., 1993; Susanne & Sharma, 1978). Additionally, orthodontists use it to determine the position and size of the jaw and the shape and size of the skull. It is also used to identify skeletal abnormalities and rule out various neurological disorders.

The facial index categorizes different facial shapes and is the ratio of the face's width to its length. It is calculated by measuring the morphological length of the face, dividing it by the bizygomatic breadth, and multiplying the result by 100. This index is widely used in recognizing human faces and is important in studying disorders and syndromes. The facial index is a valuable tool for identifying the origin of human ancestors and classifies faces into five types. The orbital index measures distances between different orbital landmarks. The orbital cavities, located between the cranium and the facial bones on either side of the midsagittal plane of the skull, study variations among different races and help identify people of various races living in a particular area.

Anthropometry: The study of the human body

Evolution is the process of genetic change over time on Earth, and these evolutionary processes occur due to factors such as nutrition, racial variations, environmental selection, and gene flow that impact the human body. Human evolution is the long process of changes in the body that are studied in anthropology (Anitha et al., 2011). Anthropology is the study of humans and their ancestors. It focuses on biological, social, physical, and cultural aspects. Physical anthropology is a branch of anthropology that focuses on the study of the origin and evolution of human beings. The interaction of environmental and sociocultural elements is a subject of physical anthropology (Chouhan et al., 2015).

The two Greek words *Anthropos*, meaning human, and *metron*, meaning to measure, are combined into the word Anthropometry. In simple terms, it can be described as the scientific study of measuring the physical properties of individuals (Ranjana et al., 2016). Anthropometry is the study of the assessment of the physiological features and characteristics of the human body using scientific methods and techniques, which aid in the observation and measurement of both living human bodies and non-living skeletons (Choudhary & Choudhary, 2012; Poswillo, 1975). It is a technique that helps in studying the various physical characteristics of the human body and is of enormous interest to scientists who have been fascinated by the variation in human biology, as it assists in studying ancestors over the years (Eickstedt, 1927).

Various studies have concluded that anthropologists claim differences in the nose—i.e., the bony nasal cavity and nasal index—are outcomes of human adaptation to climatic changes and different environmental conditions across the Earth's surface (Rajlakshmi, 2012). Basic anthropometric data of humans are required to record how the human body changes over time, and indeed the information they generate helps identify individuals from different ethnic groups, as well as their ancestors, race, gender identities, physiological conditions, and economic statuses (Jervas, 2016). India is rich in diversity in terms of culture, language, race, ethnicity, and genetic background. This diversity changes the structure of the human body, which is influenced by several variables, including the topography of an area, climate, race, gender, and age (Majumder, 1998; Rajlakshmi, 2012). The nose is an important part of the face, and the nasal index is an essential anthropometric characteristic that helps determine an individual's race from unidentified photographs, dead bodies, disasters, or war zones (Anas, 2010). Numerous techniques, including 3D scans, digitizers, morphometric analysis, cephalometry, and photography, are used to investigate the nose and determine the characteristic features of a human being. Therefore, several criteria are used to distinguish between racial and ethnic groups (Abdulrasheed & Eneye, 2013).

Nasal Index: The most important anthropological parameter

The nasal index is an important anthropometric technique for identifying sexual, racial, and ethnic distinctions among people. The form, size, and length of the nose are influenced by several factors, including age, sex, genetics, racial origins, geographic location, and regional climate changes (Ukoha et al., 2016). The nasal index, which helps to classify different types of noses, can be calculated as the ratio of nasal width to nasal bone height, multiplied by 100 (Porter & Olson, 2003).

In 1878, M. Broca was among the first to establish the nasal index as one of the most important criteria for differentiating between the existing races, and Topinard described the anthropological nasal index as the ratio of nasal breadth to nasal height (Bajracharya & Sharma, 2019). To accurately calculate the nasal index, two primary factors must be considered: nasal height and nasal width. Nasal height is determined by measuring the distance between the most lateral points of the right and left ala of the nose, while nasal width is the distance between the lower border of the nasal septum and the cutaneous portion of the upper lip (Hegazy, 2014; Ray et al., 2016; Rotimi et al., 2019). Therefore, the mathematical equation to calculate the nasal index is: (Romo & Abraham, 2003)

$$\textit{Nasal Index} = \frac{\textit{Nasal Width}}{\textit{Nasal Height}} * 100$$

Based on the general shape, there are three main types of noses: platyrrhine, characterized by a broad nose and common among African populations with a nasal index above 85.0; mesorrhine, typical among Asians, which presents a medium nose with an index ranging from 70.0 to 84.9; and leptorrhine, associated with Caucasians, which is long and narrow, with a nasal index of 70.0 or lower, typically found in colder and drier climates (Hegazy, 2014; Williams et al., 1995). Additionally, the human nose has been divided into five divisions described in the following (Table-1)

Type	Nasal Index	Shape
Hyper Leptorrhine	40 to 54.9	Very Narrow
Leptorrhine	55 to 69.9	Long and narrow
Mesorrhine	70 to 84.9	Moderate shaped (Mongoloids)
Platyrrhine	85 to 99.9	Broad and short (Negroes)
Hyper Platyrrhine	100<	Very Broad/ wide

Table-1 Classification of human nose based on nasal index

The nasal index is widely recognized as one of the most effective forensic science methods for identifying racial and ethnic distinctions among people (Aung et al., 2000; Franciscus & Long, 1991; Porter & Olson, 2003; Xu et al., 2011). This technique also aids in recognizing sexual differences (Zhang et al., 1990). Anthropologists have used the nasal index to differentiate various species of humans and distinguish between modern living races (Tahmasebi et al., 2015). According to Topinard, the nasal index is one of the best indicators for differentiating genders, races, and ethnicities (Chakravarthy, 2016). Human morphology is defined by cephalometric parameters such as the nasal index and face index (Omotoso, 2011). Using the nose as an identifying feature is one of the most crucial anthropometric methods, as it is used to determine a person's sex and ethnicity (Shrestha et al., 2019).

Several factors influence the variation in nose size between and within human populations, with genetics and environmental conditions being two key variables (Cem et al., 2001; Kasai et al., 1993). The nose, which is wide at the bottom and narrow at the top, resembles the shape of a pear and plays an essential role in respiration (Farkas & Kolar, 1987). Located in the center of the face, the nose is a crucial facial component. It is divided into the nasal cavity (cavum nasi) and the outer nasal region (often called the nasal pyramid). The external part of the nose consists of several anatomical structures, including the nasal bridge, nasal root (dorsum nasi), nasal tip, ala nasi, columella, and nostrils (anterior nares) (Asthuta & Pradiptha, 2019). The nose helps with breathing, as well as warming and moistening the inhaled air (Harzrika et al., 2007). Furthermore, the nose is regarded as one of the best indicators for tracing a person's racial origin (Madison, 2004). Climate plays a key role in shaping the type of nose; broader noses are more common in

warm, humid climates, while narrower noses are typically found in cold, dry climates (Patil et al., 2014). The nose has both external and internal components. The external nose is the visible projection from the face and is supported by a framework made of cartilage and bones (Ekwere et al., 2015). The wide variety of nose shapes and sizes found among humans is due to ethnic influences and the geographical conditions in which individuals live (Heidari et al., 2009; Last, 1981).

Cephalic Index: A scientific study of a human head

The Cephalic Index, a prominent anthropological measurement used by anthropologists to analyze the physical traits of humans, was originally developed in the nineteenth century by Swedish anatomist Anders Retzius (Boas, 1899). According to the World Health Organization, cephalometry is considered a critical index for assessing the normality of a neonate's skull and brain development (Eivazi & Farahani, 2013). Due to its simplicity and ease of use, the Cephalic Index has gained widespread popularity as it provides numerical ratios that are directly comparable and repeatable, giving a clear representation of the overall proportions of the skull (Johnson & Wilkie, 2011).

An individual's identity can often be recognized through distinctive personality traits, which set them apart from others and when someone's identity is known, it becomes much easier to investigate their demise (Ansari et al., 2021). The Cephalic Index plays a crucial role in various human-related investigations, including mixing newborns in a hospital nursery, identifying individuals during immigration procedures, and solving crimes such as burglary, robbery, human trafficking, and other criminal activities (Khair, 2013). When measuring the skull to determine the topographical relationships of specific features, both the cranial index and the cephalic index are important anthropometric parameters. Several researchers have studied the cephalic index across various populations, often without distinguishing between the skulls of men and women (Arslan et al., 2008; Bhargava & Kher, 1961).

The interaction between cranial dimensions and gene expression may cause variations among different racial and ethnic groups across geographical regions. Human identification is determined by the individuality of a person, with age, sex, and height serving as primary identification characteristics (Chouhan et al., 2015; Krishna, 2009). It is well-established that both genetic and non-genetic factors, including environmental influences and nutritional status, contribute to cranial variance observed among human populations. In addition, environmental, biological, geographic, ethnic, sex, and age-related factors all impact the physical dimensions of the human body (Khair et al., 2013).

The cephalic index is also a useful tool for representing population variation with increasing age and plays a key role in diversifying the Indian population across various geographic regions (Bharati et al., 2005; Umar et al., 2008). No two individuals share the same measured characteristics, as these traits tend to change in varying degrees from birth until death, both in healthy and unhealthy conditions. People who live in different environments and belong to various ethnic groups often exhibit significant differences in their physical attributes (Ashley, 1960). In general, determining a person's age, gender, height, and ethnicity is a critical means of individual identification (Venkatesh & David, 2011). The cephalic index also plays an essential role in comparing the cephalic morphology of siblings, children, and parents, as well as in determining patterns of inheritance (Chouhan et al., 2015).

Cephalometry, a subfield of anthropometry, involves measuring the physical dimensions of the head and face (Agarwal et al., 2014). The cephalic index, which measures the length and breadth of the head, is a valuable tool for evaluating racial and sexual differences (Akinbami, 2014). Determining the shape of the head is particularly important, as it can provide insights into the structure of the dental arch, and it remains one of the most versatile methods for studying the craniofacial skeleton due to its reliability and usefulness (Golalipour et al., 2007; Rexhepi & Meka, 2008). The cephalic index is calculated using the following formula: (Singh & Bhasin, 1968)

$$\textbf{\textit{Cephalic Index}} = \frac{\textbf{\textit{Cephalic Width}}}{\textbf{\textit{Cephalic Length}}} * \textbf{\textit{100}}$$

Human populations exhibit different types of head shapes, which are categorized based on international anatomical descriptions (William, 1995).

Type	Cephalic Index	Shape
Dolichocephalic	up to 74.9	Long (Caucasoids, Aryans, aborigines and negros)
Mesocephalic	75-79.9	Moderate (Negroids, Europeans and Indians)
Brachycephalic	80-84.9	Short (mongoloids)
Hyper Brachycephalic	85<	Short (mongoloids)

Table-2 Classification of human head based on cephalic index

The anatomical landmarks were defined as follows:

Glabella	It's a point between the eyebrows and the nasal root intersected by the midline of the skull.
Inion	The distalmost point lies on the external occipital protuberance in the mid-sagittal plane.
Euryon	On the side of the head, the lateral most point is located.

The cephalic index provides valuable data specific to demographics, age, and gender, which is instrumental in assessing an individual's development and identifying craniofacial anomalies (Harper, 1984). Notably, at the age of 14, the length of the head increases, while the head breadth reaches its maximum (Kondo et al., 1999). The mean cephalic indices of different ethnic groups vary significantly across various geographic zones. For instance, dolichocephalic head types are predominantly found in tropical regions, while mesocephalic or brachycephalic head types are more common in temperate zones (Bharati et al., 2001; Lobo et al., 2005).

The cephalic index is not only a crucial parameter for forensic medicine, anthropology, and genetics, but it also serves as a key indicator in determining sex and racial differences between individuals. These variances are influenced by a multitude of factors, including geographic location, gender, age, race, ethnicity, diet, levels of stress, access to medical facilities, overall health, and natural climate, along with various environmental conditions (Akinbami, 2014; Kumari et al., 2015).

Orbital Index: Second most important parameter for sex determination

The orbits are located in the frontal part of the skull and house the eyes. They represent the second-best anatomical feature of the human body for determining an individual's sex. The components of the orbital cavity include the eyeball, muscles, blood vessels, nerves, lacrimal apparatus, and fascial strata (Khwaja et al., 2020). The orbital index is associated with regional, sexual, and racial dimorphism, and the shape of the face is significantly influenced by the parameters of the orbital index. Paul Broca developed the orbital index in 1875 to enable a quantitative evaluation of orbital size and symmetry (Gopalakrishna & Kashinatha, 2015). This index is valuable for surgical corrections involving the human bony orbit (Rajangam et al., 2012). To gain a better understanding of the anatomical placement of the orbital components and the relevant surgical procedures, studying orbital morphological features is crucial. Additionally, the orbital index plays an important role in determining the gender and ethnicity of humans (Ghorai, 2019). The parameters included in the study are the orbital height and orbital breadth.

The orbital index is calculated by dividing the height of the orbit by its width and then multiplying the result by 100:

$$\textit{Orbital Index} = \frac{\textit{Orbital Height}}{\textit{Orbital Width}} * 100$$

Orbital breadth is defined as the distance between the midpoint of the medial margin of the orbit and the midpoint of the lateral margin of the orbit. Orbital height is the maximum distance between the upper and lower margins of the orbital cavity. The orbital index can be categorized into three distinct categories (Table 3) (Anibor et al., 2019; Hierl et al., 2022; Mottini et al., 2017).

Type	Orbital Index	Shape
Megaseme	89 or over	Large (mongoloids)
Mesoseme	83 to 89	Intermediate (Caucasoids)
Microseme	83 or less	Small (negroids)

Table-3 Classification of human orbits based on orbital index

This index is utilized by scientists and anthropologists to gather information about the history of humans and their ancestors. It is also valuable in forensic investigations. Table 4 illustrates the patterns of the orbital index (Ezeuko et al., 2014; Igbigbi & Ebite, 2010).

Type	Ancestry characteristic	Orbital opening
Megaseme	yellow races	Round
Mesoseme	white races	Intermediate
Microseme	black races	Rectangular

Table-4 Characteristics of human orbits

A thorough understanding of the normal morphometry of the orbital cavity is essential when planning surgical approaches to the orbital cavity, as well as in addressing other disorders such as congenital abnormalities and neoplastic conditions (Dvoracek et al., 2021; Ji et al., 2010; Kang et al., 2018). The orbital cavity is asymmetrical, with the right cavity typically larger than the left, a phenomenon attributed to the predominance of the left cerebral hemisphere (Jakovcevski et al., 2020; Khademi & Bayat, 2016). It has been nearly a century since the orbital index was first applied to the identity of human origins. Generally, women tend to have larger, round, narrow, and upwardly positioned orbital cavities with sharper margins, while men typically exhibit smaller, square, narrower, and downwardly positioned cavities with rounder margins (Vanrell, 2019). In terms of anthropometric characteristics, Central Europeans and Asians usually possess round orbits, while Northern and Southern Europeans, along with Africans, tend to have rectangular orbits (Biswas et al., 2015; França, 2017; Husmann & Samson, 2011; Lima et al., 2012).

Facial Index: Significant in identification of human face.

The relative proportions of the face are measured by the facial index. It is determined by dividing the maximum width of the face by its maximum length. The facial index is employed in medical research to examine facial morphology and in forensic anthropology to assist in identifying individuals. This index serves as an assessment of facial characteristics that is useful in various fields, including forensics, reconstruction, orthodontics, and anatomy (Kumari et al., 2015). Regional differences in anthropometric traits, such as stature and facial phenotype, are influenced by genetic, environmental, dietary, and climatic factors. The facial index is utilized in anthropometrics to identify ethnic variations within populations (Trivedi, 2017). Given India's diverse genetic and cultural characteristics, there is a pressing need for population-specific facial anthropometry data (Bhasin, 2006). Additionally, the facial index plays a role in the identification system known as facial recognition technology. The facial index is calculated as follows: (Devi et al., 2016)

$$\textit{Facial Index} = \frac{\textit{Facial length}}{\textit{Facial width}} * 100$$

According to (Banister et al., 1995) classification, the different varieties of faces can be divided into the five categories below based on facial index. (Table-5)

Type	Facial Index	Shape
Hyper Euryproscopic	>79.9	Very broad
Euryproscopic	80.0-84.9	Broad (Negroids)
Mesoproscopic	85.0-89.9	Round (Mongoloids)
Leptoproscopic	90.0-94.9	Long (Caucasoids)
Hyper Leptoproscopic	95.0 <	Very long

Table-5 Classification of human face based on facial index

Euriprosopics are characterized by short, broad faces with a facial index ranging from 80 to 84.9. *Mesoprosopics* have average round faces with facial index values between 85 and 89.9. *Leptoprosopic* facial features exhibit facial index scores between 90 and 94.9. *Hypereuriprosopic* and *hyperleptoprosopic* facial index values are defined as less than 79.9 and greater than 95, respectively (Shetti et al., 2011; Vangara et al., 2021; Yesmin et al., 2014). Each distinct attribute of a person's facial features serves as a hallmark of their specific racial or ethnic origin, facilitating identification and the performance of reconstructive surgeries. Furthermore, the facial form exhibits sexual dimorphism, manifesting different traits in males and females (Osunwoke et al., 2011; Shah et al., 2015).

Thus, these indicators are valuable tools for understanding human evolution and the biological adaptations that have accompanied it, as they quantify the characteristic features of humans within a community. Additionally, they are frequently used to examine variations in evolution and to enhance our understanding of human ancestry.

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