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A comparison between Chinese and Caucasian head shapes☆

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ABSTRACT

Univariate anthropometric data have long documented a difference in head shape proportion between Chinese and Caucasian populations. This difference has made it impossible to create eyewear, helmets and facemasks that fit both groups well. However, it has been unknown to what extend and precisely how the two populations differ from each other in form. In this study, we applied geometric morphometrics to dense surface data to quantify and characterize the shape differences using a large data set from two recent 3D anthropometric surveys, one in North America and Europe, and one in China. The comparison showed the significant variations between head shapes of the two groups and results demonstrated that Chinese heads were rounder than Caucasian counterparts, with a flatter back and forehead. The quantitative measurements and analyses of these shape differences may be applied in many fields, including anthropometrics, product design, cranial surgery and cranial therapy.

1. Introduction

Knowledge of the form of the human head is essential information for a variety of fields, including design, medicine and anthropometrics (Coblentz et al., 1991; Farkas, 1994; Kouchi and Mochimaru, 2004; Meunier et al., 2000). The differences in head dimensions among various populations have been studied (Lee and Park, 2008; Yokota, 2005). It has also been suggested by both popular anecdote and traditional univariate anthropometric dimensions (Farkas, 1994) that Chinese and Western heads are different. This cultural difference has made it impossible to create eyewear, protective helmets and hygienic facemasks that fit both groups well, as shown by the recent marketing trend advertising “Asian fit” versions of high-end fashion eyeglasses. However, it has remained unknown to what extent and in precisely what way the Chinese and Western heads differ from each other in 3D shape.

Traditionally, univariate anthropometrical measurements of human body using tape and caliper were commonly taken to compare the cultural difference due to its simplicity (Farkas, 1994). Later on, digitizer (Liu et al., 1999; Wang et al., 2005) and other methods were used to collect 3D landmark coordinates which can be used for statistical shape analysis (Bookstein, 1991; Badawi-Fayad and Cabanis, 2007; Mutsvangwa and Douglas, 2007). However, the information of 1D dimension and sparse 3D landmarks could not satisfy the fitting requirements of products (Goonetilleke and Luximon, 2001; Meunier et al., 2000). In order to capture more detailed 3D geometry of human body, researchers started using CT scan (Chen et al., 2002; Niu et al., 2009) and stereophotogrammetry (Coblentz et al., 1991). Even though these 3D geometries have brought new information for anthropometry area, it has been found that the technologies could not be applied to a large number of subjects due to the procedure and difficulty of data processing. Recently, 3D laser surface imaging technology has allowed digitization to record the entire surface of the subjects as a 3D point cloud with high density (Ball and Molenbroek, 2008; Goonetilleke and Luximon, 2001; Krauss et al., 2008; Meunier et al., 2000; Robinette et al., 2002; Witana et al., 2009). The method for processing the huge amount of laser scanning data has become a new challenge for analyses.

Several surface modelling and shape description methods have been applied to 3D anthropometric data processing. In theoretical applications, geometric morphometrics have been widely used to study shape variations in biological forms in evolution (Collard and O’Higgins, 2000), paleoanthropology (Ponce de Leon and Zollikofer, 2001), and medical research (Hammond et al., 2004; Hennessy et al., 2007). Kouchi and Tsutsumi (1996) studied morphological characteristics of cross-section of 3D foot shape model to find out the relation between foot outline medial axis and 3D shape. A 3D face form using the free form deformation method was analyzed for spectacle frames design (Kouchi and Mochimaru, 2004).

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In addition, the non-uniform rational Bsplines (NURBS) method was applied to reconstruct 3D human heads (Zhang and Molenbroek, 2004). Recently, surface parameterization method has been used on 3D human body frequently (Allen et al., 2003; Xi et al., 2007; Xi and Shu, 2009). When the data is manipulated with the surface parameterization technique, a statistical shape analysis comparison can be performed on whole surfaces with dense sample of coordinates. Consistent parameterization (Xi et al., 2007; Xi and Shu, 2009) deformed a generic mesh model and fit it onto each human head scan. This method has ensured that all the parameterized models are well corresponded in 3D positions where anthropometric landmarks locate, and the other parts on the parameterized models are corresponded accordingly. As a result, the same vertices denote the same semantic position on each parameterized head model. The 3D consistent parameterization thus creates a solid basis for latter comparisons, because it represents the individual head shape in all directions and local positions consistently. This approach has been shown previously to be effective in studying the relationship between human facial dysmorphogenesis and cognitive function (Hennessy et al., 2007), 3D human shape variations within a population (Xi and Shu, 2009). Based on the theory of the method development, it will be appropriate method on statistical comparison of different populations.

Therefore, the main objective of this study is to compare the 3D shape differences between Chinese and Western heads using 3D anthropometrical data through various methods including parameterization technique, contour and landmarks. The quantitative measurements and analyses of these shape differences will help to answer practical questions in many fields, including anthropometrics, product design, cranial surgery and cranial therapy.

2. Methods

In order to compare the head shape differences between Chinese and Western population, 3D head shape data was obtained from two recent digital anthropometric databases, one representing North American and European Caucasians (CAESAR) and the other representing the Chinese (SizeChina). The parameterized models, the characteristic contour and the selected landmarks of these two data sets were processed and compared statistically.

2.1. Data acquisition

2.1.1. SizeChina database

SizeChina was the first high resolution 3D digital anthropometric survey using laser scan technology to study the size and shape of the adult Chinese head (Ball and Molenbroek, 2008). The project was inspired by the widespread perception that headgear designed using Caucasian data was unsuitable for Asian users. Using Cyberware 3030 Color 3D scanner (www.cyberware.com), SizeChina documented head data from both men and women between the ages of 18 and 70+. The scanner captured a cylinder space about 30 cm in height and 40–50 cm in diameter. The sampling pitch or scanning resolution of scanner used in SizeChina survey was 1° on theta, 0.7 mm on y (vertical) and minimum 0.1 mm on z (diameter). Scanning was conducted at six different mainland sites (Shenyang, Beijing, Lanzhou, Chongqing, Hangzhou, Guangzhou), chosen to represent a broad geographical range between north, south, east and west recording a total of more than 2000 subjects. No restrictions were placed on the height, weight or socio-economic status of volunteer subjects. Data collected from each subject included standard univariate measurements including weight, height and head dimensions; high resolution digital photographs of front and side profiles; demographic data; and the 3D digital scans.

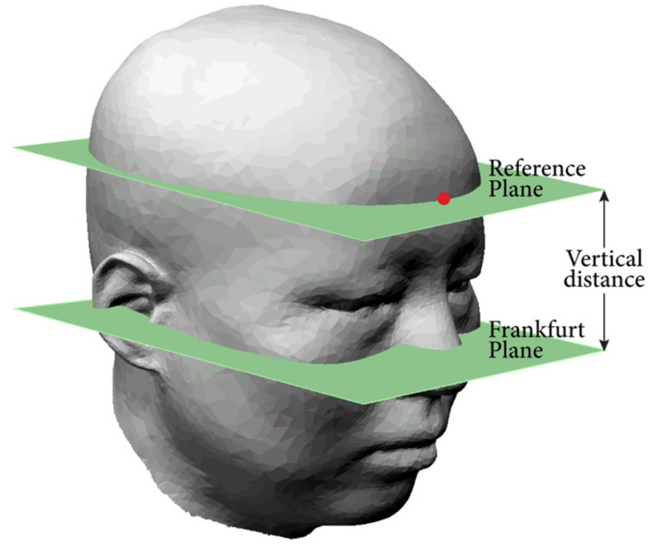

Fig. 1. Location of Reference Plane for characteristic contour.

2.1.2. CAESAR database

The Civilian American and European Surface Anthropometry Resource (CAESAR) (Robinette et al., 2002) offered an extensive 3D digital database recording scan measurements of male and female adult civilian subjects aged 18–65. CAESAR was the first large-scale anthropometric study to record 3D digital scans of body shape in addition to traditional univariate measurements and demographic data. Digital scan data recorded the geometry of body shape in full 3D space, providing a detailed and accurate description of body shape, as well as automatic consistency in data collection. The 4000

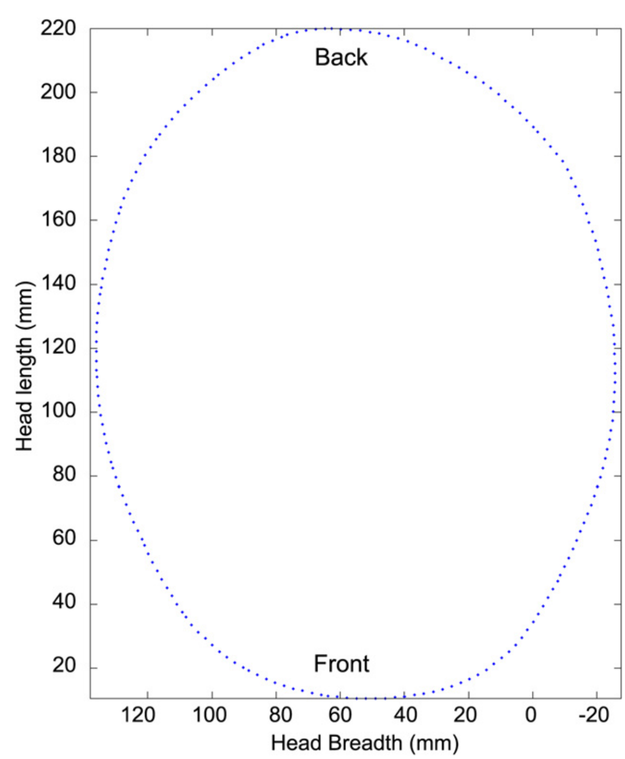

Fig. 2. An example of characteristic contour.