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Sexual dimorphism in the facial morphology of adult humans: A three-dimensional analysis

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ABSTRACT

The objective of this study was to demonstrate sexual dimorphism in the entire three-dimensional facial surface form of adult humans. The sample consisted of female and male groups ($n = 200$; age range, 18–35 years). Three-dimensional images of each participant's face at rest were recorded. A total of 185 variables that described facial surface configuration features were extracted from each image. The variables were compared between the groups using *t*-tests, and those exhibiting *P*-values <0.0001 were entered into a stepwise discriminant function analysis for sex determination. Wire mesh fitting was also performed on each image to examine the facial surface morphology. The mean node coordinates of the fitted mesh were compared between the groups using *t*-tests. Sixty-seven of the 185 variables differed significantly between the groups, and 11 qualified for inclusion in the stepwise analysis. The female group exhibited a greater vertical height of the eye fissure, shorter postero-anterior height of the nasal tip, vertically greater supraorbital ridge, shorter lower face height relative to the total upper anterior face height, more prominent cheeks in the infraorbital region, less prominent cheeks in the buccal region, shorter vertical height of the subnasal region, a smaller nasal hump, and a smaller alar. The discriminant function analysis was 96.5% accurate overall.

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The wire mesh fitting results showed that the eyes, forehead, and chin were in vertically higher positions in the female group than in the male group. The cheeks and nose were more protuberant in the female group and male group, respectively.

Introduction

Humans are capable of categorizing human faces by sex with approximately 98% accuracy (Saether et al., 2009), and can also differentiate between males and females using three-dimensional (3-D) facial images without skin texture (imageless 3-D shapes) with 75% accuracy (Bruce et al., 1993). Another study showed that humans can more accurately categorize human faces by sex from 3-D facial images than from 2-D images (O'Toole et al., 1997). In terms of human visual perception, sexual dimorphism exists in 3-D facial surfaces. Regarding cues for visual judgments, the available evidence suggests that males tend to use zygomatic bones, chin prominence, and inner face breadth as clues to make categorization judgments (Pivonkova et al., 2011). During face recognition, the preferred landing position of eye fixation is between the nose and the eyes in the frontal view and between the eye and the zygomatic bone in the lateral view (Saether et al., 2009). Therefore, we anticipate that humans use crucial features of the entire human 3-D facial surface, including the eye, nose, cheek, and chin regions, to discriminate between males and females.

Numerous methods have been used in attempts to establish "absolute" sex differences in facial morphological characteristics, including 3-D analyses, e.g., direct anthropometry of the human face (Bigoni et al., 2010; Mane et al., 2011; Rosas and Bastir, 2002), stereophotogrammetry (Dong et al., 2010), laser scanning (Hennessy et al., 2002), videotape tracking (Giovanoli et al., 2003), and computed tomography (Coquerelle et al., 2011). Female faces have been found to be smaller than male faces (Anić-Milosević et al., 2009). Many features related to the hard tissues of the face are sexually dimorphic: adult female faces exhibit a more gradual inclination of the nasal bones (Rosas and Bastir, 2002), shallower curvature of the base of the nose (Bigoni et al., 2010), smaller piriform aperture (Rosas and Bastir, 2002), shorter mandibular symphysis height (Thayer and Dobson, 2010), and less protrusive mandibular mentum osseum (Rosas and Bastir, 2002; Thayer and Dobson, 2010) than male faces. There are also differences in the soft tissues of the face, with female adults exhibiting more retruded chins (Valenzano et al., 2006), a more forward position of the gonion (Valenzano et al., 2006), and a vertically lower position of the labiomental sulcus (Dong et al., 2010) than male adults.

These analyses were conducted primarily using linear and/or angular measurements between and among the landmarks and were unsuitable for gaining a holistic understanding of the morphological traits of the entire face with its soft tissues. A few attempts have been made to extract detailed morphological characteristics of soft-tissue facial configurations using sliced lines or surface voxels, but these were limited to local segments (chins or mandibles) rather than addressing the entire face (Coquerelle et al., 2011; Thayer and Dobson, 2010). Interestingly, a previous study using ultrasound showed that females have greater soft tissue thickness in the zygomatic region (De Greef et al., 2006). Another study using moiré tomography showed qualitatively that females have angulated-type cheeks while males have massive-type cheeks (Ikeda et al., 1999). No study, however, has examined the morphological traits of the cheeks in a quantitative manner. It remains unclear whether entire 3-D soft tissue facial configurations are sexually dimorphic.

The objectives of this study, therefore, were as follows: (1) to verify if there exits sex difference in the inter-landmark variables of adult human faces, (2) to establish new variables characteristic of the entire 3-D facial surface that can serve to distinguish between males and females, and (3) to clarify whether entire 3-D facial surface forms are sexually dimorphic based on those variables.