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Visualizing Facial Shape Regression upon 2nd to 4th Digit Ratio and Testosterone

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ABSTRACT

Sex steroids are supposed to moderate the differences between male and female facial characteristics. Studies on women's preferences for male faces reported increased preferences for facial architecture developed under the influence of testosterone as this may indicate masculinity, dominance and social status. Recent research demonstrates that facial sexual dimorphism does not only develop at puberty but may be organized much earlier in ontogeny. However, the actual cause and timing of variation in facial shape due to sex-steroids remains speculative. This study uses data from Neave and colleagues[1] who measured digit ratio (2D:4D) as a proxy to prenatal testosterone and also salivary testosterone samples in order to study differential effects of androgens on perceived male facial shape. Male facial shape was regressed upon 2D:4D ratio and circulating levels of testosterone by means of geometric morphometric methods. We found some evidence for opposite effects of early androgen action (via 2D:4D ratio) on the upper and the lower face respectively (i.e. low 2D:4D ratio results in a relatively robust and prominent lower face), whereas circulating testosterone seems to cause a rather uniform elongation of the face. Local deformations primarily show pronounced and medially tailed eyebrows for the shapes associated with increasing salivary testosterone. These preliminary results suggest that prenatal and pubertal testosterone have differential effects on male facial shape that should be considered in future studies on women's preferences towards male facial appearance.

Key words: *2D:4D, digit ratio, testosterone, males, facial shape, geometric morphometrics*

Introduction

Some proportions of the human face are sexually dimorphic. Typical male traits develop under the influence of testosterone whereas female traits are formed under the *absence* of high testosterone. In pubertal males, a high testosterone/estrogen ratio is supposed to facilitate the lateral growth of the cheekbones, mandibles and chin, the forward growth of the bones of the eyebrow ridges, and the lengthening of the lower face[2,3]. Evolutionary psychology suggests that females should have evolved preferences for such facial characteristics and consider them attractive because they signal health, developmental stability, dominance and masculinity[4]. There are several studies that lend support to the view that women's preferences for facial 'hormone markers' may reflect an index of mate quality[5]. However, evidence on the causal relation between testosterone and male facial characteristics still remains speculative, though a recent study by Penton-Voak and Chen[6] reports preliminary findings of a link between high salivary testosterone and 'masculine' facial appearance.

Neave, Laing, Fink and Manning[1] found that the relative length of the 2nd (index) to 4th (ring) finger (2D:4D ratio), which is known to be negatively correlated with prenatal testosterone[7,8], was significantly negatively correlated with ratings of perceived male dominance and masculinity, but not attractiveness. In contrast to Penton-Voak and Chen[6], circulating levels of testosterone analysed from salivary samples did not correlate with ratings of dominance, masculinity or attractiveness.

A more recent study by Fink and colleagues[9] demonstrates that prenatal sex steroids (as measured via 2D:4D ratio), particularly testosterone, affect facial ar-

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chitecture. Clearly, characteristics that are considered typically 'male' were found to correspond to low 2D:4D ratios, whereas some typically 'female' features corresponded to high 2D:4D ratios. These authors further showed that 2D:4D affects male and female face shape by similar patterns, but was three times more intense in men than in women. Hence, testosterone seems to be a powerful hormone with regard to its effects on face shape and this may apply not only at puberty but much earlier in ontogeny. However, this suggestion contrasts earlier findings about associations between actual levels of testosterone and facial characteristics.

There is, to the best of our knowledge, no data available that deal with the action of both early and adult circulating testosterone in more detail. In the present study we examine adult male facial shape by means of geometric morphometric methods[10] (see methods section) based on the data of Neave and colleagues[1] and present preliminary results and visualization of facial shape in relation to 2D:4D ratio and circulating testosterone. On the basis of the recent results by Fink and others[9], namely the fact that effects of 2D:4D on face shape show a different pattern from actual facial sexual dimorphism, we hypothesize that the inconsistency in literature about the testosterone and face shape association may be due to testosterone determining dissimilar shape patterns at different developmental stages.

Material and Methods

We used the data set as published in Neave et al.[1] Therefore we only provide basic information concerning data recording, and focus on the novel methodology of the present study, i.e., the analysis and visualization of prenatal and adult testosterone effects upon male facial shape by means of geometric morphometric measurement.

Data recording

Our data set comprised 48 heterosexual, right-handed male participants aged 18–33 years (mean age= 21.3, SD= 3.4). Measurements of the lengths of the 2nd (index finger, 2D) and 4th (ring finger, 4D) digits were available as were digital facial images. Calculated repeatabilities for successive measurements were reported in the original paper to be high. Forty-six participants provided a salivary sample from which circulating levels of free testosterone were measured with Coat-A-Count total testosterone kits (Euro/DPC, Wales, UK) (for details on the recoding procedure and assay methodology see Neave et al.[1]).

Soft tissue measurement points

Fifty-one somatometric landmarks[11] were selected to cover all facial regions (Figure 1) and digitized within the 'Beautynet' software environment as two-dimensional (2D) coordinates on each of the photographs (see for details Grammer et al.[12]) by one of the authors (B.F.) experienced in this task.

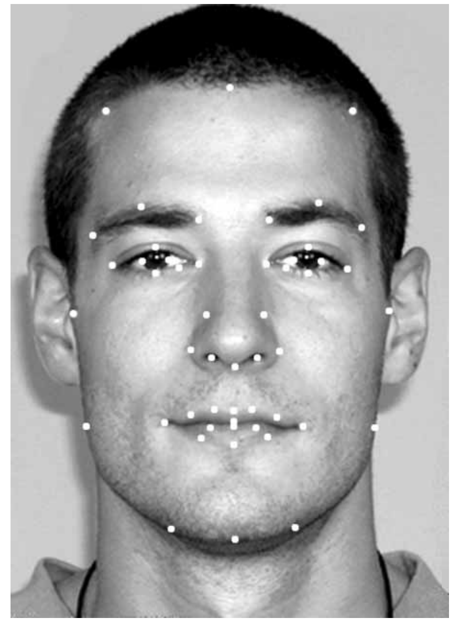

Fig. 1. Fifty-one somatometric landmarks were digitized as two-dimensional (2D) coordinates on each of the facial photographs.

Geometric morphometric analyses

For the analyses of facial shape, we use geometric morphometrics, an approach deriving from multivariate statistical analyses of Cartesian coordinate data[10,13]. For the registration of the 46 configurations with 51 2D landmark points each, we applied the standard Procrustes analysis method[14–16], which results in a set of vectors of 102 shape coordinates.

In order to determine the shape change associated with a parameter of interest, a linear regression function is calculated for every shape coordinate separately, where the slopes of the functions predict the shape change that occurs within one unit of the independent variable. The alpha level of significance of the regressions was calculated by a Monte Carlo permutation test[17] with the generalized shape variance explained by the regression (sum of the variances explained by 2D:4D or testosterone over all the shape coordinates separately) as the test statistic. Thin-plate spline (TPS) deformation grids are used for visualization. Bookstein[10] proposed the TPS interpolation formalism to visualize differences in the positions of landmarks by modelling the deformations taking place between the landmarks, i.e. in all regions without landmark points. Shape regressions are visualized by computing the mean form (consensus) and adding the respective slope to the corresponding shape variable. Since the changes within one unit are often small, the slopes are usually multiplied by an arbitrary factor to enhance visualization. All statistical computations were done in Mathematica 5.0 (Wolfram Research, Inc.).

Results

The 2D:4D ratios were similar for both hands (left hand: X±SD=0.96±0.03, range 0.89–1.02; right hand: X±SD= 0.96±0.03, range 0.88–1.01), and significantly positively correlated (Pearson's r=0.639, p<0.001). As such, they were averaged among both hands and the analyses performed with the resulting composite ratio.

A two-block Partial Least Squares analysis[10] of the shape coordinates (first block) against testosterone and 2D:4D ratio (second block), determining the import of either block on the other, revealed that facial shape is predicted by both factors with almost equal power (singular values 0.010 and 0.008). The two shape regression vectors of 2D:4D ratio and testosterone, however, are almost orthogonal to each other (angle of 80.6 degree), indicating no interrelation among them.

In order to investigate to what extent and into which direction the 2D:4D ratio systematically affects male facial features we regressed the 46 vectors of the 102 shape coordinates (resulting from the 51 somatometric landmarks per image after the Procrustes fit) upon the 46 respective 2D:4D ratio values. This shape regression is visualized in Figure 2a by means of TPS deformation grids. The middle panel shows the mean landmark configuration of the sample, characterized by the rectangular grid with uniform quadratic units, the neighbouring panels represent both directions of the predicted deformation. The panel on the left side shows the deformation associated with higher 2D:4D ratio (i.e. lower levels of prenatal testosterone). The main effect is a grid contraction in the lower face and a widening of the meshes in the upper face, indicating a smaller chin, a narrowing of the midface, and a relative expansion of the forehead. The opposite holds for the image on the right, visualizing the shape changes with lower 2D:4D ratio (i.e. higher levels of prenatal testosterone): the grid indicates a relative enlargement of the whole lower face achieved by a broadening of the zygomatic arch and a more prominent chin. The eyebrows follow this pattern.

Salivary testosterone levels of the sample ranged from 4.49 to 15.95 ng/dL (X=8.94, SD=2.67). In order to investigate to what extent and into which direction testosterone systematically affects male facial features, we performed a shape regression upon these values. Figure 2b visualizes that regression using TPS deformation grids for the predicted transformation in both directions from the average (middle panel). The left grid shows the facial shape change associated with decreasing salivary

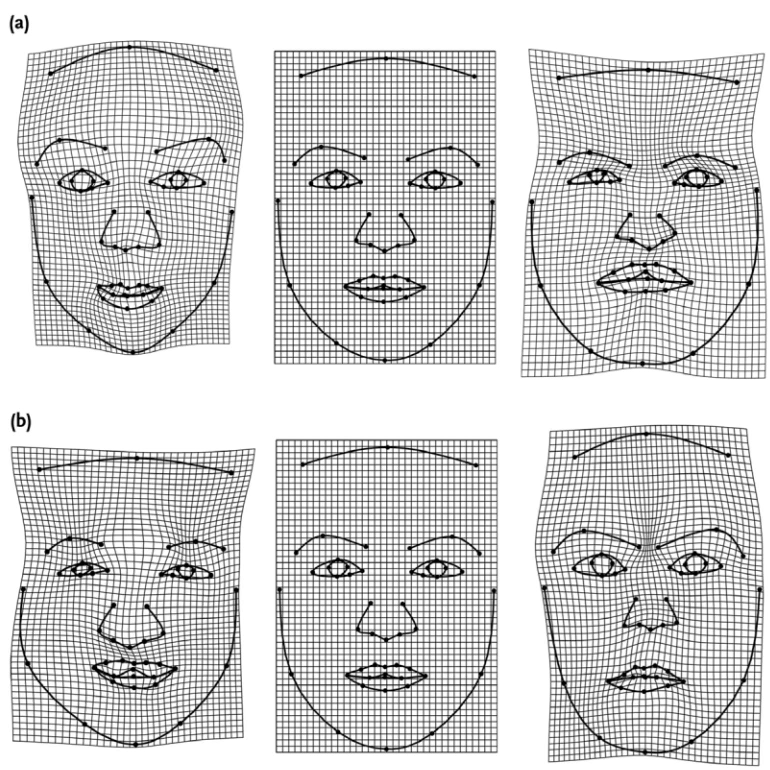

Fig. 2. (a) Thin plate spline visualization grids of the shape regression upon 2D:4D ratio. The left deformation grid shows the consensus (middle panel) deformation towards lower prenatal testosterone levels (higher 2D:4D ratio), while the right grid corresponds to shape changes associated with higher prenatal testosterone levels (both splines multiplied by factor of 0.25 for visibility). Some landmarks (black dots) are connected by lines (cubic splines) for illustration. (b) Thin plate spline visualization grids of the shape regression upon salivary testosterone. The left deformation grid shows the consensus deformation towards lower salivary testosterone levels, while the right grid corresponds to shape changes associated with increasing testosterone levels (splines exaggerated by factor of 20 for visibility).

testosterone levels whereas the right grid illustrates the deformation corresponding to increasing levels. The most obvious and general difference is the primarily horizontal grid compression in the former as opposed to a more vertical stretching in the grid describing higher testosterone levels: a rounded versus an elongated face. A second, more local distinction is found in the region of the eyes: while the shapes that correspond to lower testosterone show small eyebrows and narrow eyes, the deformation towards higher testosterone levels shows rounder eyes with eyebrows expanding laterally and, especially, medially. In both shape regressions the explained variance does not exceed 5% (2.5% for 2D:4D, 2.1 % for salivary testosterone), and does not yield significance by permutation test[17] after 10,000 permutations (p>0.05, p=0.6 for 2D:4D, p=0.3 for circulating testosterone).

Discussion

The present study examined male facial shape in relation to indicators of prenatal and circulating levels of testosterone (as measured via 2D:4D ratio and saliva respectively). We found some evidence that early androgen action operates in contrasting ways on the upper and the lower face while circulating levels of testosterone seem to cause a rather uniform elongation of the face. Neave et al.[1] suggested that high prenatal levels of testosterone (resulting in a low 2D:4D ratio) 'organise' male facial features (presumably activated during puberty) that may subsequently reflect dominance/masculine characteristics. In light of the present analysis, the visualization of face shape regressions upon 2D:4D ratio indicates that low 2D:4D faces are evidently more robust than high 2D:4D faces. Our data further indicate that circulating levels of testosterone in turn do not cause this effect on male facial shape.

The *pattern* for the effect of 2D:4D on male facial shape demonstrated here is in accord with the recent study by Fink et al.[9] who also found low 2D:4D ratios to be associated with the same robust facial shape in both men and women. Interestingly enough, this connection was found to be significant only in men which points to testosterone as the responsible candidate rather than to the testosterone/estrogen ratio[9]. Moreover, this pattern supports the notion that 2D:4D ratio manifests itself in a broadening of the o*s zygomaticum* and the mandible, facial characteristics that are known to be assessed as dominant and masculine[1,18,19]. Taken together it seems that there is accumulating evidence for the effect of prenatal testosterone upon facial shape: higher levels of testosterone *in utero* presumably promote the development of robust facial architecture. These effects certainly contribute to the stamping of the adult male face but cannot be simply equated with total sexual dimorphism.

High circulating testosterone levels, in turn, seem to determine a facial elongation pattern, maybe more related to extended growth. In addition, the pronounced and medially almost fusing eyebrows are likewise absent in the low 2D:4D shapes. It has been proposed that the eyebrows receive the highest rank in the order of magnitude of perceived gender information carried by parts of the face[20]. Evidently, such facial characteristics define the scope of a different domain than the one pertaining to prenatal testosterone. However, there is more research needed to yield the appropriate fine-grained picture of the hormonal operations at different ages (including growth) composing the final form of the adult male and female human face. The apparent limitation of the present study is its sample size (N=46), which restricts the analysis to be exploratory and permits statements only about trends, though there is a picture emerging about the morphological effects of prenatal, pubertal and adult testosterone (and their respective perceptions) that seems worth pursuing in future studies. It remains to be explained why women seem to find the high-testosterone traits attractive.

In conclusion, the contributions of the present study are twofold. First, although numerous studies of adult male facial appearance have assumed an association with hormone levels, there was hitherto no data available that has actually visualized, detailed, and compared variation in facial shape in relation to circulating and prenatal testosterone. Second, our visualisations support the claims of Neave et al.[1] that some of the adult male facial characteristics (known to be perceived as dominant and masculine) might be determined very early in ontogeny.

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VIZUALIZACIJA ODNOSA OBLIKA LICA PREMA OMJERU VELIČINE DRUGOG I ČETVRTOG PRSTA RUKE I RAZINI TESTOSTERONA

S A Ž E T A K

Pretpostavlja se da spolni steroidi moderiraju razlike između muških i ženskih obilježja lica. Dosadašnja istraživanja su pokazala veću sklonost žena za arhitekturu muških lica razvijenu pod utjecajem testosterona jer ona indicira muževnost, dominaciju i društveni status. Studija koja je nedavno provedena pokazala je da se spolni dimorfizam lica ne razvija samo u vrijeme puberteta već može biti uspostavljen puno ranije u ontogenetskom razvoju. Međutim, stvarni uzrok kao i vrijeme nastanka varijacija oblika lica koje su pod utjecajem spolnih steroida još uvijek su samo spekulativni. U svrhu istraživanja diferencijalnog utjecaja androgena na doživljaj muževnosti lica, ova studija koristi podatke Neave i suradnika[1] koji su prikupili uzorke testosterona sline ali su i mjerili omjer duljine drugog i četvrtog prsta ruke (2D:4D) koji odražava učinke testosterona u prenatalno doba. Geometrijsko-morfometrijskim metodama napravljena je regresija muškog oblika lica prema omjeru 2D:4D i razini cirkulirajućeg testosterona. Rezultati su pokazali da rano djelovanje androgena (putem 2D:4D omjera) ima suprotne učinke na gornji u odnosu na donji dio lica. Tako nizak 2D:4D omjer odgovara relativno robusnom i upadljivom donjem dijelu lica dok izgleda da cirkulirajući testosteron uzrokuje prilično ravnomjernu elongaciju lica. Izražene i medijalno povezane obrve nisu pokazale odnos s omjerom 2D:4D već su povezane samo s povećanim vrijednostima testosterona u slini. Ovi preliminarni rezultati sugeriraju da vrijednosti testosterona u prenatalno doba i u vrijeme puberteta imaju različite učinke na formiranje muških obilježja lica. Ovu činjenicu trebalo bi uzeti u obzir prilikom budućih istraživanja sklonosti žena prema izgledu muških lica.