

## Short Report

## Body Fat and Facial Shape Are Correlated in Female Adolescents

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**Objectives:** Relative body weight is not only an important indicator for health and reproductive condition, but also subject to stereotypes and stigmatization. It can be reliably assessed from adult faces alone, yet the facial correlates, especially in adolescents, remain largely unidentified. This study was designed to determine the facial features of adolescent girls that change with body fat proportion using a modern, comprehensive technique for shape analysis.

**Methods:** Standardized frontal facial photographs of 22 Caucasian female adolescents (mean age  $15.8 \pm 2.7$  years) were taken, and body height, body weight, and body fat proportion measured. Seventy-two somatometric measurement points were digitized on each photograph and their Cartesian coordinates regressed onto body fat proportion. Geometric morphometrics also enabled visualizing the statistical results as shapes.

**Results:** Body fat proportion explained 8.7% of the facial shape variation (10,000 permutations,  $P = 0.047$ ). Girls with high body fat had a relatively rounder and larger lower face, relatively smaller eyes, and a shorter and wider nose, fuller lips and downturned corners of the mouth. Low body fat was associated with a more angular lower face and a pointier chin, relatively larger eyes and a longer nose. The lips were wider and thinner, the corners of the mouth upturned.

**Conclusion:** Body fat proportion is a substantial factor in facial shape variation of female adolescents. The potential influence of the corresponding facial features on social perception is discussed. Prospects for future research including novel possibilities for stimuli design (GM morphs) are highlighted. *Am. J. Hum. Biol.* 25:847–850, 2013. © 2013 Wiley Periodicals, Inc.

Although the quantitative literature on adiposity and obesity is huge, that dealing with under- or overweight associated with facial shape changes is not. This holds especially true for children and juveniles. Our study identifies the facial morphological correlates of body fat in female adolescents.

On one hand, by buffering famine, malnutrition, and fluctuations in dietary energy supply, the fat content of adipose tissue plays an important role in enhancing reproductive fitness, including trans generational transfers of energy. Accordingly, it might be subject to sexual selection. On the other hand, the direction of selection varies with ecological conditions (Tovée et al., 2006): in places of constant nutritional oversupply, persons with high levels of body fat are confronted with negative attitudes and stereotypes, and suffer from low self-esteem (e.g., Puhl and Latner, 2007).

For adult faces, Coetzee et al. (2009) confirmed the presence of facial cues to body weight, in so far as people quite adequately judged under-, normal- and overweight from frontal photographs of the face alone. Tinlin et al. (2013) replicated this finding in American women. There now is cross-cultural evidence that the cheeks and relative jaw width are the most affected by nutritional condition in terms of adult facial tissue depth (Wilkinson, 2004 for a review; Coetzee et al., 2010 in Caucasian and African faces, Lee et al., 2012 in Korean faces). The literature on adolescents is scarcer. Ferrario et al. (2004), however, identified larger transverse distances (facial widths) at *Tragion* (proxy for cheek area) and *Gonion* (lower face) as well as greater anteriorposterior distances (facial depths) in the lower face with increasing body mass index (BMI) in Italian girls. Earlier studies were limited by a morphometric approach based on distances, angles, or ratios. Geometric morphometrics, instead, is based on the

Cartesian coordinates of the measurement points allowing the preservation of the relative spatial arrangements throughout the analysis, and thus enables more powerful statistics and visualization techniques (see the recent *Hystrix* special issue on geometric morphometrics for details, Vol. 24, June 2013).

The current study investigates the association of body fat and facial shape in female adolescents using geometric morphometrics. Although BMI is an accurate estimate for body fat mass among obese adolescents, BMI differences among thinner children can be largely due to fat-free mass (Freedman et al., 2005) because BMI does not distinguish between body fat and muscle mass which weighs more than fat. As in adults, cheek and jaw prominence are expected to increase with body fat adding to a rounder face outline (e.g., Windhager et al., 2011). Predicted local feature differences include the relative decrease of the eye region (e.g., Lee et al., 2012) and a smaller mouth (both found for adult men, Windhager et al., 2011).

#### METHOD

##### Participants

The final dataset comprised 22 Austrian female adolescents with a mean age of  $15.8 \pm 2.7$  years (range: 10–20 years). Their body fat ranged from 10.6 to 44.8%. Based on the criteria of McCarthy et al. (2006), 5 adolescents

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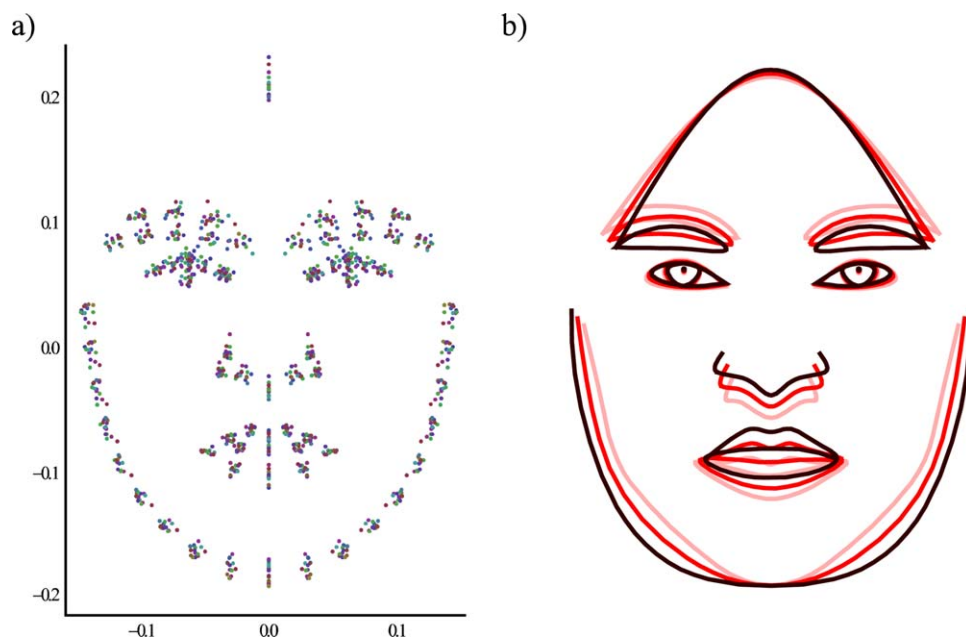


Fig. 1. Shape analysis using geometric morphometrics. (a) The 22 landmark configurations, after Procrustes superimposition and symmetrization, as used for subsequent statistical shape analysis. (b) Result of the shape regression: the three facial configurations ( $-5$  SD body fat—sample average— $+5$  SD body fat proportion) of Figure 2 superimposed to simplify comparison. The darker the line, the higher the body fat proportion. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://wileyonlinelibrary.com).]

could be classified as “underfat,” 14 as “normal” (spread over all five subcategories), two as “overfat,” and one as “obese.” Neither body fat proportion nor body fat percentile groups were significantly correlated with age (Spearman  $r$ 's  $< -0.24$ ,  $P = 0.3$  each,  $n = 22$ ), so that the depicted association of facial shape and body fat cannot be attributed to age-related growth. Facial and anthropometric data were collected in Vienna, Austria, in 2010 and 2011.

#### Procedure

Frontal photographs were taken at a standardized distance and at eye height with a digital reflex camera (Canon EOS 40D) and a 200 mm lens. The adolescents were instructed to adjust their heads according to the Frankfort horizontal plane and to look straight into the camera with a neutral expression. Body weight and body fat were measured with a body fat scale (Tanita TBF 105), body height using an anthropometer. BMI and body fat proportion were highly correlated ( $r = 0.864$ ,  $P \leq 0.001$ ,  $n = 22$ ). Body fat proportion was used for further analysis. All adolescents agreed to participate in this study, and their parents signed a consent form.

#### Statistical analyses

Seventy-two somatometric landmarks and semilandmarks (mainly following Windhager et al., 2011) were digitized on each face. After generalized Procrustes superimposition, sliding, and symmetrization, the resulting shape coordinates (Fig. 1a) were analyzed using a shape regression (linear regressions of the shape coordinates upon body fat proportion) in order to determine the association between facial shape and body fat. To test for statistical significance, a permutation test was computed. These geometric morphometric methods have been sum-

marized in the work by Mitteroecker and Gunz (2009). Thin-plate spline (TPS) deformation grids and geometric morphometric morphs (= GM morphs; i.e., statistical image morphs based on the shape regression) were used for visualization.

The analyses were carried out in PASW 18 (descriptives, correlations), tpsDig2 (digitizing the landmarks), tpsRelw (sliding, Procrustes superimposition), tpsRegr (shape regression, permutation test), tpsSuper (image unwarping and image averaging for GM morphs), and Mathematica 8 (symmetrization, thin-plate spline deformation grids). The tps-Program series is by Rohlf (2004–2009).

## RESULTS

Body fat proportion explained 8.7% of facial shape variation ( $P = 0.047$ ; 10,000 permutations). The TPS deformation grids in Figure 2 (top row) depict the shape changes from the sample average face (middle panel) to the face of a girl with lower (left panel) and to one with higher body fat proportion (right panel). Additionally, GM morphs (unwarped and averaged photographs) show the same pattern (Fig. 2, bottom row). Both the deformation grids and the GM morphs were exaggerated for readability toward  $-5$  and  $+5$  standard deviations of the mean body fat proportion. Figure 1b shows the three configurations superimposed.

A low body fat proportion (left column Fig. 2) was associated with a wider forehead. The visible parts of the eyes were relatively larger and accompanied by higher, more curved eyebrows. The nose appeared to be longer and narrower. The relatively wider mouth had upturned corners and thinner lips. These girls with low body fat generally

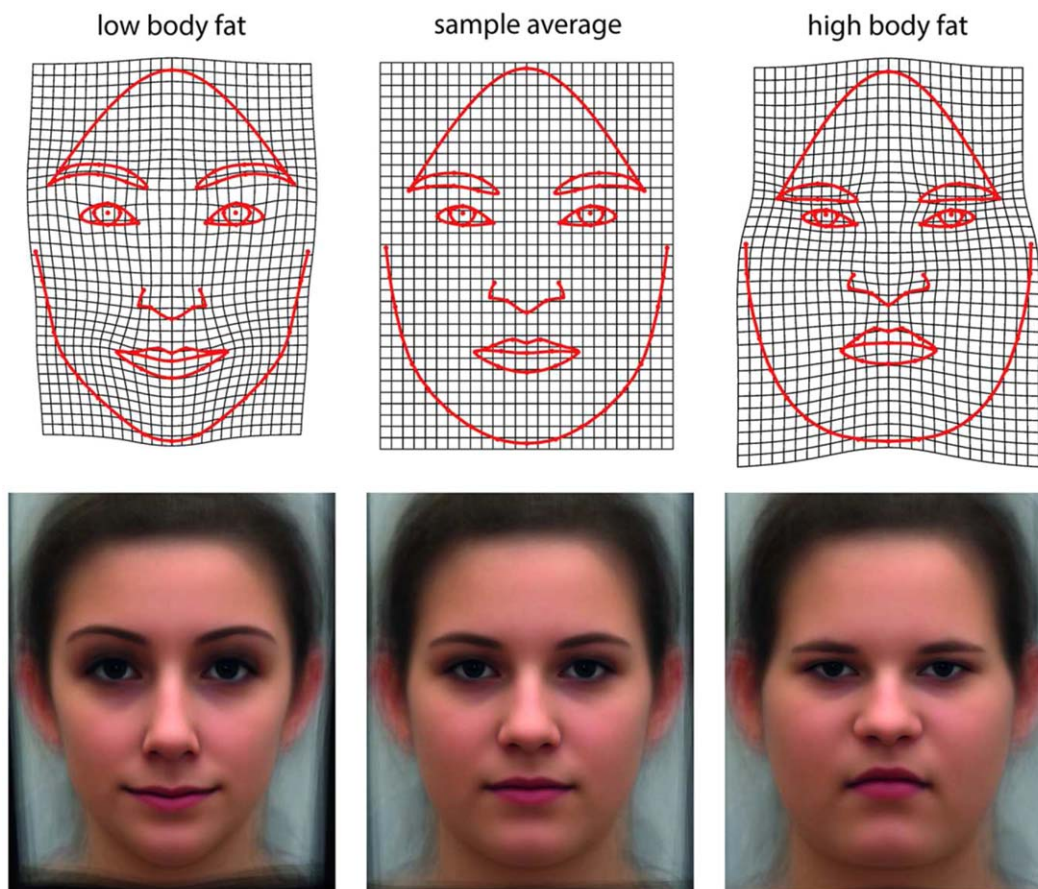


Fig. 2. Visualization of the shape regression upon body fat proportion (8.7% var. explained,  $P < 0.05$ ,  $n = 22$ ). Thin-plate spline deformation grids (top row) together with GM morphs (unwarped and averaged photographs, bottom row) depict the association between body fat and facial shape in female adolescents. The panels show the sample average (23% body fat, middle column), and the facial configurations corresponding to  $-5$  ( $-19\%$  body fat, left column) and  $+5$  standard deviations (64% body fat, right column) of the mean body fat proportion. Connecting cubic splines between landmarks are drawn for visualization purposes. [Color figure can be viewed in the online issue, which is available at [wileyonlinelibrary.com](http://wileyonlinelibrary.com).]

had a more angular face with narrower cheeks, a longer mid-face, and a shorter lower face with a more pointed chin. The whole jaw outline was narrower than in faces associated with higher body fat. Girls with a high body fat proportion (right column Fig. 2), in contrast, had a relatively larger lower face with a wider jaw outline. The eyebrows were lower and flatter and the visible parts of the eye comparably small. These girls generally shared a wider mid- and lower face due to a broader chin and cheek area. The nose was shorter and wider. The lips were fuller and the corners of the narrower mouth downturned.

#### DISCUSSION

The amount of visceral fat (“belly fat”, as opposed to subcutaneous fat) has been confirmed to positively correlate with facial (buccal) fat ( $r = 0.5$ ; Levine et al., 1998). Here, we show that body fat proportion plays an important role in facial shape variation of female adolescents. In line with Ferrario et al. (2004) and previous research on adult women (Coetzee et al., 2010; Lee et al., 2012), we identify a relative widening of the mid- and lower face with increasing body fat. We also found the reduced eye height and the wider nose, as described for Korean women

(Lee et al., 2012). The shape of the mouth had, to our knowledge, not been addressed in association with BMI or body fat in the female sex so far. Except for this feature, our results match those for adult men (Windhager et al., 2011). In female adolescents, we now report thicker lips with increasing body fat, as well as down-turned corners of the mouth, despite the participants’ emotionally neutral facial display.

It remains to be determined whether the larger, rounded mid- and lower face with increased body fat proportion elicits associations with (i) babies’ chubby cheeks (Wilkinson, 2004; Zebrowitz et al., 1998), or rather with (ii) masculinity and dominance due to the relative jaw prominence (e.g., Windhager et al., 2011). The smaller eyes, the lower eyebrows, and the downturned corners of the mouth probably add to the latter. As trait attributions influence social interaction, these competing hypotheses need to be tested. Male and especially female adolescents are known to pick a feminized over a masculinized face when asked to choose the more attractive girl or boy (Saxton et al., 2011). In adult women, intermediate levels of perceived facial adiposity are judged as most attractive and healthiest (Coetzee et al., 2009). Furthermore, overweight and obese adolescents are especially vulnerable to

weight biases, stereotypes, and stigmatization from their peers (Puhl and Latner, 2007). The negative attributes that such girls encounter include being lazy, unclean, eating too much, enjoying fighting, as well as being unable to dance or get a boyfriend. It remains to be determined whether the facial morphology associated with high body fat already provokes the negative attitudes and behaviors caused by excess body fat.

The morphometric techniques employed here not only allowed to isolate, quantify, and plot the shape changes that are determined by a particular variable, but also enabled the design of facial stimuli where only this variable is systematically varied. Finally, direct behavioral observations might help elucidate self-fulfilling prophecies and compensatory behaviors in every-day life (as in Zebrowitz et al., 1998 for boys).

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