Original Article

Soft Tissue Facial Morphology in Obese Adolescents: A Three-Dimensional Noninvasive Assessment

Virgilio F. Ferrario, MD[a]; Claudia Dellavia, DDS[b]; Gianluca M. Tartaglia, DDS, PhD[c]; Michela Turci, PhD[b]; Chiarella Sforza, MD[a]

Abstract: The number of obese adolescents is increasing in the Western society. For a deeper understanding of the mechanisms underlying this pathology, the quantitative characteristics of the facial soft tissues should also be investigated. The three-dimensional coordinates of 12 soft tissue facial landmarks were obtained by computerized digitizers in 11 male and 14 female adolescents aged 13–17 years, all with a body mass index larger than 30 kg/m^2 (mean 31.67 kg/m^2, SD 1.58). From the landmarks, several facial dimensions were calculated. Data were compared with those collected in normal individuals of the same age, ethnicity, and sex by computing *z* scores. Significant (paired Student's *t*-test, $P < .05$) larger dimensions were found for skull base width (girls), mandibular width (both sexes), lower face depth (girls), and mandibular corpus length (girls). In the pooled sample (boys plus girls), the faces of obese adolescents were significantly wider transversally (skull base width, mandibular width), deeper sagittally (mid and lower face depth, mandibular corpus length), and shorter vertically (upper facial height) than those of their normal school companions. ''Borderline'' obese adolescents possessed some facial characteristics typical of patients with more substantial obesity. The effect of an increased body weight-per-height was therefore present also in subjects not already referred to a medical control. (*Angle Orthod* 2004;74:37–42.)

Key Words: Anthropometry; Face; Obesity; Soft tissues; Three-dimensional

INTRODUCTION

In European and North American children and adolescents, the prevalence of obesity is increasing.[1–4] An obese child has an increased risk of becoming an obese adult,[2,3] a condition considered a risk factor for several cardiovascular and metabolic pathologies.[3,5–7] Also, obesity is a major risk factor for obstructive sleep apnea.[8]

The effects of an altered body growth on craniofacial structures have been studied in children, adolescents, and adults with reduced somatic growth of different causes (endocrine diseases, such as growth hormone deficiency, or short stature of prenatal origin).[9,10] In contrast, there is only scanty data on the reactions of the craniofacial complex to an overall increase in the body mass. A recent quantitative investigation performed on obese adolescents analyzed the hard-tissue situation of the craniofacial skeleton, as depicted by lateral plane radiographs.[11] Unfortunately, radiographic analyses are invasive, and for ethical reasons, it is often difficult to obtain data on normal individuals.[12] In contrast, anthropometry is noninvasive. Furthermore, it is three-dimensional, and it considers all the facial structures, thus providing a more complete evaluation of the single patient.[13–16] The collection of normative data does not infringe any current ethical consideration. Simple anthropometric assessments have already been used as a screening tool to predict whether a patient has obstructive sleep apnea.[17]

Currently, anthropometric evaluations are also considered an important low-cost method for the first assessment

[a] Professor of Human Anatomy, Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (LAFAS) & Laboratorio di Anatomia Funzionale dell'Apparato Locomotore (LAFAL), Functional Anatomy Research Center (FARC), Dipartimento di Anatomia Umana, Facoltà di Medicina e Chirurgia and Facoltà di Scienze Motorie, Università degli Studi di Milano, Milano, Italy.

[b] Postgraduate Student, Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (LAFAS) & Laboratorio di Anatomia Funzionale dell'Apparato Locomotore (LAFAL), Functional Anatomy Research Center (FARC), Dipartimento di Anatomia Umana, Facoltà di Medicina e Chirurgia and Facoltà di Scienze Motorie, Università degli Studi di Milano, Milano, Italy.

[c] Research Assistant, Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (LAFAS) & Laboratorio di Anatomia Funzionale dell'Apparato Locomotore (LAFAL), Functional Anatomy Research Center (FARC), Dipartimento di Anatomia Umana, Facoltà di Medicina e Chirurgia and Facoltà di Scienze Motorie, Università degli Studi di Milano, Milano, Italy.

Corresponding author: Virgilio F. Ferrario, MD, Dipartimento di Anatomia Umana, via Mangiagalli 31, I-20133 Milano, Italy (e-mail: farc@unimi.it).

Accepted: March 2003. Submitted: February 2003.

of the nutritional level and general health condition of adolescents.[18,19] In particular, the body mass index (BMI, the ratio of body weight to squared standing height, kg/m^2) has been found to possess a high specificity and to be efficient as an indicator of overweight in nutritional and general health screenings.[3,5,6,19–21] In adolescents, BMI is strongly associated with fatness.

The quantitative assessment of craniofacial variations is commonly used for the characterization of diseased subjects[14,16,22] and it may play a role in the anatomical and clinical description of obese individuals also.[17] Both skeletal and soft tissue structures should be analyzed to provide a complete evaluation of any given individual in all three dimensions.

Current technology provides several image analysis systems for indirect computerized facial anthropometry: stereophotogrammetry, laser scanning, range cameras, optoelectronic instruments, and electromagnetic digitizers.[15,22–26] These instruments provide the three-dimensional coordinates of selected landmarks, and Euclidean geometric calculations can then be used to obtain three-dimensional linear distances of selected facial structures.[15,24]

To the best of our knowledge, no previous analysis has quantified the three-dimensional characteristics of the facial soft tissues of obese adolescents. In the present study, the facial soft tissues of a group of adolescents with a BMI larger than 30 kg/m^2 have been measured in the three-dimensional space and their facial dimensions calculated and compared with a reference normal population.

MATERIALS AND METHODS

Sample

From the database of the Laboratorio di Anatomia Funzionale dell'Apparato Stomatognatico (University of Milan, Italy), data from 25 adolescents (11 boys, 14 girls) aged 13 to 17 years (mean 15.43 years, SD 1.25) all with a BMI larger than 30 kg/m^2 were retrieved (Table 1). Mean *z* scores of standing height of the adolescents were −0.60 (boys, SD 1.61) and −0.16 (girls, SD 1.25). All adolescents were white northern Italians. The adolescents were not enrolled in a clinical contest and were not seeking medical intervention, but their measurements were taken during our previous longitudinal and cross-sectional investigations of craniofacial growth and development performed in schools of Milan (northern Italy) and its surrounding areas.[25,26] Each adolescent entered the study only once. Subjects with previous history of craniofacial trauma or congenital anomalies were not included in the samples.

From the same database, reference data collected on normal subjects of the same ethnic group, age, and sex were also obtained.[25,26] Each reference group (for each age and sex) comprised at least 60 subjects, and normal adolescents, 456 girls and 324 boys, were considered in the current study. Boys had a mean BMI of 20.36 kg/m^2; girls had a mean BMI of 21.3 kg/m^2.

All the analyzed individuals, and their parents or legal guardians gave their informed consent to the experiment.

Collection of three-dimensional facial landmarks

A detailed description of the data collection procedure can be found elsewhere.[15] In brief, for each subject, a single experienced operator located and marked 50 landmarks on the cutaneous surface. Three-dimensional coordinates of the facial landmarks were then obtained with a computerized electromagnetic digitizer (3Draw, Polhemus Inc., Colchester, Vt). Three-dimensional (x, y, z) coordinates were recorded and analyzed using customized computer algorithms written by one of the authors. The reproducibility of landmark identification, marker positioning, and data collection procedure has been previously reported and found to be reliable.[15] Landmark positions were defined according to Farkas.[13]

The following soft tissue landmarks were used in the present study (Figure 1).

- Midline landmarks—tr, trichion; n, nasion; sn, subnasale; pg, pogonion.
- Paired landmarks (right and left side noted r and l)—ex_r, ex_l, exocanthion; t_r, t_l, tragion; ch_r, ch_l, cheilion; go_r, go_l, gonion.

Midlandmarks were also mathematically derived as the midpoint between two homologous landmarks and noted as $landmark_m$.

Data analysis

Computer programs devised and written by one of the authors were used for all the subsequent calculations. According to the geometric models of the face defined by Ferrario et al,[15,24] the x, y, z coordinates of the landmarks obtained on each subject were used to calculate the following facial dimensions (in mm).

- Transverse distances (widths)—biorbital width, ex_r-ex_l; skull base width, t_r-t_l; mandibular (intergonial) width, go_r-go_l; mouth width, ch_r-ch_l.
- Vertical distances (heights)—forehead height, tr-n; upper facial height, n-sn; lower facial height, sn-pg; facial height, n-pg.
- Anteroposterior distances (depths)—upper face depth, n-t_m; mid face depth, sn-t_m; lower face depth, pg-t_m; mandibular corpus length, pg-go_m.

All the measurements were performed in the three-dimensional space, ie, the position of the points relative to all three planes (frontal, lateral, and horizontal) was considered at the same time (no projections).

TABLE 1. Descriptive Statistics of *z* Scores Computed in 25 Obese Adolescents[a]

	Boys (n = 11)			Girls (n = 14)			Pooled		
	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
Age (y)	14.68[b]	1.07	—	16.02[b]	1.07	—	15.43	1.25	—
BMI (kg/m^2)	30.88[b]	0.79	—	32.29[b]	1.78	—	31.67	1.58	—
z Scores									
ex-ex	0.19	1.38	NS	0.59	1.60	NS	0.41	1.49	NS
t-t	0.28	1.21	NS	0.94	1.42	.033	0.65	1.34	.026
go-go	1.11	1.11	.01	1.48	1.27	.001	1.32	1.19	.001
ch-ch	−0.32	1.41	NS	0.22	1.65	NS	−0.01	1.55	NS
tr-n	0.33	0.98	NS	−0.20	0.99	NS	0.04	1.00	NS
n-sn	−0.45	1.46	NS	−0.61	1.11	NS	−0.54	1.25	.045
sn-pg	0.48	0.74	NS	0.09	1.10	NS	0.26	0.96	NS
n-pg	0.17	1.07	NS	−0.32	1.13	NS	−0.10	1.11	NS
n-t_m	0.23	1.29	NS	0.55	0.76	NS	0.41	1.02	NS
sn-t_m	0.19	1.16	NS	0.76	0.82	NS	0.51	1.00	.02
pg-t_m	0.99	1.16	NS	0.81	0.82	.003	0.89	0.97	.001
pg-go_m	0.43	1.11	NS	0.70	0.91	.016	0.58	0.99	.008

[a] *P* indicates probability of Student's *t*-test for paired samples; NS, not significant ($P > .05$).
[b] Boys and girls differ significantly (Student's *t*-test for independent samples, 23 degrees of freedom, $P = .007$ for age, $P = .028$ for BMI).

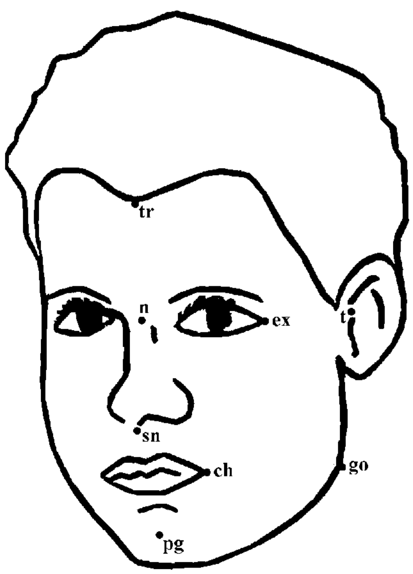

FIGURE 1. Soft tissue facial landmarks digitized on all patients.

Statistical calculations

Individual measurements obtained in the 25 adolescents were transformed to *z* scores by subtracting from each value its sex and age reference mean value and dividing by the relevant reference standard deviation. Descriptive statistics (mean and standard deviation) were computed for the values of the *z* scores separately for boys and girls, as well as for the pooled sample.

Statistical comparisons were performed by paired Student's *t*-tests (null hypothesis—the *z* scores should be zero if facial dimensions in obese adolescents do not differ from the reference population; alternative hypothesis—*z* scores significantly different from zero) and unpaired Student's *t*-tests (null hypothesis—values obtained for boys are not different from those for girls; alternative hypothesis—values obtained for boys are different from those for girls). A *P* value of .05 or smaller was considered significant.

RESULTS

On average, adolescent girls were significantly older (1.7 years) than adolescent boys and had a significantly larger BMI (Table 1). In contrast, the *z* scores did not differ significantly between sexes (Student's *t*-test for independent samples, $P > .05$ in all occasions), and pooled values were computed.

Overall, most variables were larger in obese adolescents than in their normal peers (positive *z* values), even if they did not all reach statistical significance. Significant (paired Student's *t*-test, $P < .05$) positive differences were found for skull base width (girls), mandibular (intergonial) width (both sexes), lower face depth (girls), and mandibular corpus length (girls). Obese adolescents boys had a smaller mouth (ch-ch) and a smaller upper facial height (n-sn) than normal adolescents. In obese adolescent girls, three vertical dimensions were smaller (forehead, upper facial height, and total facial height) than those measured in normal adolescents. None of these negative values was significantly different from zero ($P > .05$).

In the pooled sample (boys plus girls), obese adolescents appeared to possess faces that were significantly wider transversally (skull base width, mandibular width), deeper sagittally (mid and lower face depth, mandibular corpus length), and shorter vertically (upper facial height) than those of the reference group. As an example, the soft tissue facial features of an obese adolescent boy as compared with

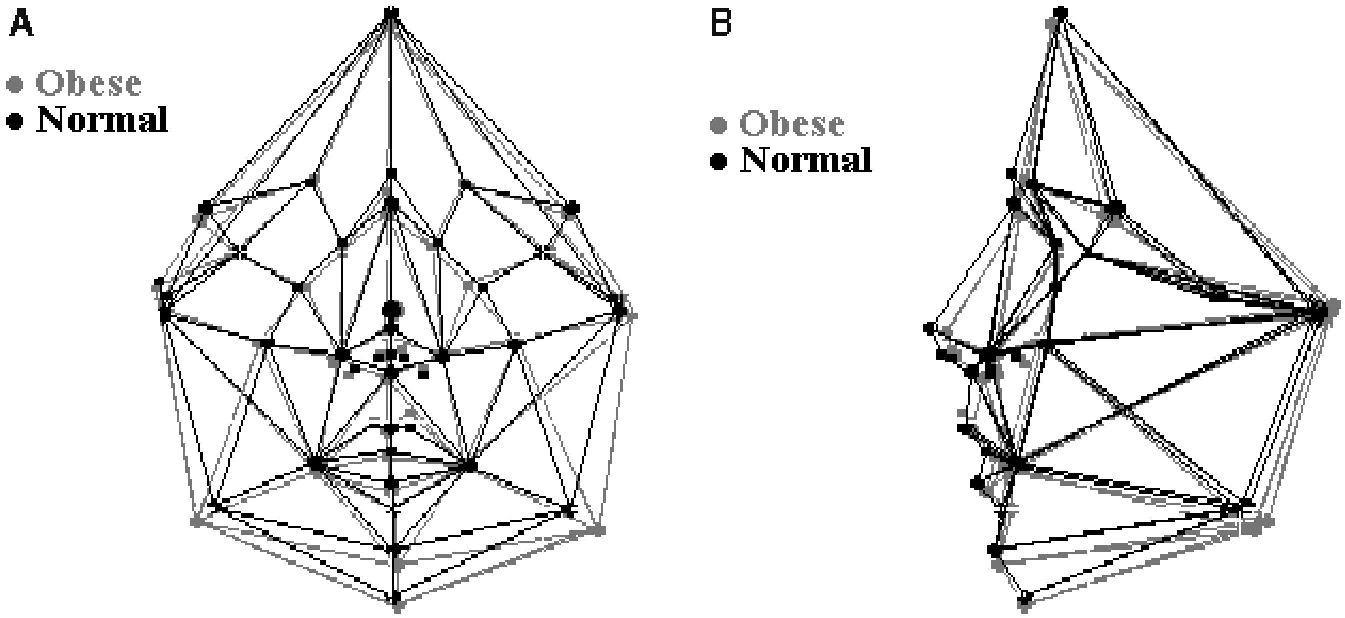

FIGURE 2. Facial soft tissues of an obese adolescent boy (gray lines and dots) superimposed on the tissues of the sex- and age-related normal adolescents (black lines and dots). (A) Frontal view. (B) Lateral view.

his sex- and age-related normal reference group are depicted in Figure 2.

DISCUSSION

Reference anthropometric data of the face are not only essential for the quantitative description of normal individuals, but they could also be used profitably in diagnostic procedures.[14,16,22,23] To differentiate between different pathologies as well as between individual morphologic variations, measurements are essential.[16]

In the present study, a three-dimensional noninvasive system allowed the quantitative analysis of the soft tissue facial characteristics in a group of obese adolescents. Data were compared with those collected in normal subjects of the same age, sex, and ethnic group by using z scores. This method allows standardization of single measurements obtained from individuals of different ages and sexes and comparison of equivalent values.[14,16] The use of z scores allowed the comparison of adolescent boys and girls of different ages. Facial dimensions are modified during growth and development with sex-related characteristics,[11,24–26] and the analysis of simple (nonstandardized) facial dimensions may not be informative.

The obese adolescents who participated in this study were not enrolled in a clinical contest and were not seeking medical intervention, but their measurements were taken during our longitudinal and crosssectional investigations of craniofacial growth and development performed within junior high schools and high schools.[25,26] Therefore, their obesity was limited, with BMI ranging between 30.03 and 36.69 kg/m^2. In contrast, the adolescents analyzed by Ohrn et al[11] ranged at a minimum between 33.44 and 45.1 kg/m^2 (an approximate calculation computed from their mean and standard deviation).

The threshold value chosen in the current study was suggested by Ohrn et al.[11] In nutritional studies, an obese adolescent is defined as a subject with a BMI larger than 30 kg/m^2 or larger than the 95th percentile for age and sex, whichever is smaller.[3,6,20,27] The use of the 95th percentile of the relevant age-, sex-, and race-specific distribution of BMI may be more accurate,[5,19] but the present criterion of inclusion could be considered correct as a first screening.

A further confounding factor in the definition of a threshold for adolescent obesity is the general maturation of the subject as related to the timing of puberty.[11,18,27] Subjects tall for their age and with a faster maturation are often with extreme BMI,[27] and therefore a combination of BMI, skinfold thickness, and maturation state may be more appropriate, especially in a clinical context.[18]

Unfortunately, no data (such as modifications in facial hair or voice changes) on the maturation state of the present adolescents were available. The mean z scores of standing height of the present subjects were within a normal range, especially in girls, and their general somatic growth could be considered within the normal variations.[9,27] Therefore, the differences in their facial dimensions seem to be directly related only to obesity, as suggested in the study by Ohrn et al[11] for differences between obese and normal adolescents similar to those found in the current investigation.

Soft tissue facial morphology has been sparingly studied in obese patients, and a limited number of investigations can be found, for instance, the use of oral diameters, neck circumference, and BMI as a screening tool for obstructive sleep apnea.[17] In the radiographic study by Ohrn et al,[11] the analysis was limited to the growth patterns of skeletal structures, and no data were reported on facial soft tissues. In the present study, computerized indirect anthropometry allowed a fast investigation (less than one minute of data collection, the complete set of data of one subject is available off-line in 10 minutes) of all three facial thirds in all three spatial dimensions.[15] The adolescents had no biological price to pay, a crucial consideration when analyzing nonpatient growing subjects.[12]

Overall, the current results are in good agreement with the findings obtained by Ohrn et al[11] in a somewhat larger number of patients: a general increment in facial dimensions of obese adolescents, an increase in mandibular length, a reduction in upper anterior facial height. Apart from the already mentioned variations in BMI values, some differences between the two investigations have to be underlined: the girls who participated in this study were about 0.3 years older, the study was three-dimensional and not limited to the sagittal plane, both hard and soft facial tissues were considered. Although the age difference may probably have not influenced the results in normal (nonobese) adolescent girls,[24–26] there are no data about its effect in obese girls. The introduction of a third dimension also allowed the assessment of transverse facial measurements. The increment in transverse facial dimensions found in the obese adolescents is in general agreement with previous findings of larger facial dimensions in the anterior-posterior and vertical dimensions.[11]

CONCLUSIONS

The analysis of the global facial appearance, obtained by the soft tissue cover of an underlying skeletal frame, allowed a more comprehensive study of obese subjects.[17] The most important finding is that ‘‘borderline’’ obese adolescents (mean BMI 31.67 kg/m^2) also possessed some facial characteristics typical of patients with a more substantial obesity (mean BMI 38.2 kg/m^2). The effect of an increased body weight-per-height is therefore present also in the face of subjects not already referred to a medical control.

REFERENCES

1. Kromeyer-Hauschild K, Zellner K, Jaeger U, Hoyer H. Prevalence of overweight and obesity among school children in Jena (Germany). *Int J Obes.* 1999;23:1143–1150.
2. Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British birth cohort. *Am J Clin Nutr.* 1997;66:1094–1101.
3. Rosner B, Prineas R, Loggie J, Daniels SR. Percentiles for body mass index in U.S. children 5 to 17 years of age. *J Pediatr.* 1998; 132:211–222.
4. Turci M, Grassi GP, Sforza C. Anthropometric variables in high-school students in northern Italy during a school year. *Acta Med Auxol.* 1997;29:87–99.
5. Falorni A, Galmacci G, Bini V, et al. Fasting serum leptin levels in the analysis of body mass index cut-off values: are they useful for overweight screening in children and adolescents? A school population-based survey in three provinces of central Italy. *Int J Obes.* 1998;22:1197–1208.
6. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. *Am J Clin Nutr.* 1994;59:307–316.
7. Rabkin SW, Chen Y, Leiter L, Liu L, Reeder BA. Canadian Heart Health Surveys Research Group. Risk factor correlates of body mass index. *Can Med Assoc J.* 1997;157:S26–S31.
8. Tangugsorn V, Krogstad O, Espleland L, Lyberg T. Obstructive sleep apnea: a canonical correlation of cephalometric and selected demographic variables in obese and nonobese patients. *Angle Orthod.* 2001;71:23–25.
9. Kjellberg H, Beiring M, Albertsson Wikland K. Craniofacial morphology, dental occlusion, tooth eruption, and dental maturity in boys of short stature with or without growth hormone deficiency. *Eur J Oral Sci.* 2000;108:359–367.
10. Van Erum R, Mulier M, Carels C, de Zegher F. Short stature of prenatal origin: craniofacial growth and dental maturation. *Eur J Orthod.* 1998;20:417–425.
11. Ohrn K, Al-Kahlili B, Huggare J, Forsberg C-M, Marcus C, Dahllof G. Craniofacial morphology in obese adolescents. *Acta Odontol Scand.* 2002;60:193–197.
12. Solow B, Ovesen J, Wurtzen Nielsen P, Wildschiodtz G, Tallgren A. Head posture in obstructive sleep apnoea. *Eur J Orthod.* 1993; 15:107–114.
13. Farkas LG. Examination. In: Farkas LG, ed. *Anthropometry of the Head and Face.* 2nd ed. New York, NY: Raven Press; 1994; 3–56.
14. Farkas LG, Katic MJ, Forrest CR. Age-related changes in anthropometric measurements in the craniofacial regions and in height in Down’s syndrome. *J Craniofac Surg.* 2002;13:614–622.
15. Ferrario VF, Sforza C, Poggio CE, Cova M, Tartaglia G. Preliminary evaluation of an electromagnetic three-dimensional digitizer in facial anthropometry. *Cleft Palate-Craniofac J.* 1998;35:9–15.
16. Ward RE, Jamison PL, Allanson JE. Quantitative approach to identifying abnormal variation in the human face exemplified by a study of 278 individual with five craniofacial syndromes. *Am J Med Genet.* 2000;91:8–17.
17. Kushida CA, Efron B, Guilleminault C. A predictive morphometric model for the obstructive sleep apnea syndrome. *Ann Intern Med.* 1997;127:581–587.
18. de Onis M, Habicht J-P. Anthropometric reference data for international use: recommendations from World Health Organization Expert Committee. *Am J Clin Nutr.* 1996;64:650–658.
19. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH. Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescent. *Am J Clin Nutr.* 2002;75:978–985.
20. Dietz WH, Robinson TN. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. *J Pediatr.* 1998;132:191–193.
21. Malina RM, Katzmarzyk PT. Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents. *Am J Clin Nutr.* 1999;70:131s–136s.
22. Shaner DJ, Peterson AE, Beattie OB, Bamforth JS. Assessment

of soft tissue facial asymmetry in medically normal and syndrome-affected individuals by analysis of landmarks and measurements. *Am J Med Genet.* 2000;93:143–154.
23. Duffy S, Noar JH, Evans RD, Sanders R. Three-dimensional analysis of the child cleft face. *Cleft Palate-Craniofac J.* 2000;37:137–144.
24. Ferrario VF, Sforza C, Poggio CE, Schmitz JH. Facial volume changes during normal human growth and development. *Anat Rec.* 1998;250:480–487.
25. Ferrario VF, Sforza C, Colombo A, Schmitz JH, Serrao G. Morphometry of the orbital region: a soft-tissue study from adolescence to mid-adulthood. *Plast Reconstr Surg.* 2001;108:285–292.
26. Ferrario VF, Sforza C, Serrao G, Ciusa V, Dellavia C. Growth and aging of facial soft-tissues: a computerised three-dimensional mesh diagram analysis. *Clin Anat.* In press.
27. Freeman JV, Power C, Rodgers B. Weight-for-height indices of adiposity: relationships with height in childhood and early adult life. *Int J Epidemiol.* 1995;24:970–976.