

Soft tissue facial angles in Down's syndrome subjects: a three-dimensional non-invasive study

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SUMMARY The aim of the present study was to obtain quantitative information concerning the three-dimensional (3D) arrangement of the facial soft tissues of subjects with Down's syndrome. The 3D co-ordinates of 50 soft tissue facial landmarks were recorded by an electromechanical digitizer in 17 male and 11 female subjects with Down's syndrome aged 12–45 years, and in 429 healthy individuals of the same age, ethnicity and gender. From the landmark co-ordinates, geometric calculations were obtained of several 3D facial angles: facial convexity in the horizontal plane (upper facial convexity, mid facial convexity including the nose, and lower facial convexity), mandibular corpus convexity in the horizontal plane, facial convexity including the nose, facial convexity excluding the nose, interlabial angle, nasolabial angle, angle of nasal convexity, left and right soft tissue gonial angles. Data were compared with that collected for the normal subjects by computing the z-scores.

Facial convexity in the horizontal plane (both in the upper and mid facial third), facial convexity in the sagittal plane and the angle of nasal convexity were significantly ($P < 0.05$) increased (flatter) in subjects with Down's syndrome than in the normal controls. Both left and right soft tissue gonial angles were significantly reduced (more acute) in the Down's syndrome subjects. Subjects with Down's syndrome had a more hypoplastic facial middle third with reduced nasal protrusion, and a reduced lower facial third (mandible) than reference, normal subjects.

Introduction

Facial anthroposcopy (observation) and anthropometry (measurement) play a key role in the diagnosis of several dysmorphic syndromes (Allanson *et al.*, 1999; Ward *et al.*, 2000; Farkas *et al.*, 2001a, b, 2002a, b; Guyot *et al.*, 2001, 2003; Meintjes *et al.*, 2002; Moore *et al.*, 2002; Zankl *et al.*, 2002; Douglas *et al.*, 2003; Zankl and Molinari, 2003).

Quantitative soft tissue facial data in three dimensions can be obtained by both conventional and digital computerized anthropometry. While the role of conventional anthropometry has been well recognized by clinicians working with the maxillofacial complex (Allanson *et al.*, 1999; Ward *et al.*, 2000; Farkas *et al.*, 2001a, b, 2002a, b; Guyot *et al.*, 2001, 2003; Moore *et al.*, 2002), computerized anthropometry is still not widely used (Coward *et al.*, 2000; Duffy *et al.*, 2000; Meintjes *et al.*, 2002; Douglas *et al.*, 2003; Guyot *et al.*, 2003). This method could overcome some of the limitations of conventional anthropometry (namely, it is time-consuming, very demanding for both the clinician and the patient, it necessitates very well-trained and experienced examiners, and it does not provide co-ordinate data that could be used to measure a new set of features), thus providing a very useful tool for the analysis of individuals with a disability (Duffy *et al.*, 2000; Meintjes *et al.*, 2002; Douglas *et al.*, 2003).

Conventional anthropometry has been widely used for the characterization of the soft tissue facial features of

individuals with Down's syndrome. This syndrome is the most frequent live-born autosomal aneuploidy in humans. The clinical entity, first described in 1866 (Minderer *et al.*, 2003), is produced by the trisomy of chromosome 21 (Desai, 1997; Quintanilla *et al.*, 2002; Roizen and Patterson, 2003; Tuxen *et al.*, 2003). Affected individuals have several abnormalities of body organs and systems, with a variable phenotypic pattern (Desai, 1997; Richtsmeier *et al.*, 2000; Tuxen *et al.*, 2003). Among the most constant features, there is a distinctive and immediately recognizable craniofacial phenotype (Richtsmeier *et al.*, 2000, 2002). The principal stigmata include modifications in head size (overall reduction) and shape (brachycephaly with a flattened occipital bone), a diminished anterior cranial base, reductions in maxillary and mandibular size, decreased interorbital distance together with small palpebral fissures, a small mid-face with reduced nasal protrusion, and small ear length and width (Desai, 1997; Richtsmeier *et al.*, 2000, 2002; Farkas *et al.*, 2001a, b, 2002a, b; Quintanilla *et al.*, 2002; Bagic and Verzak, 2003; Roizen and Patterson, 2003). The facial profile may also sometimes be concave, with a prominent forehead and mandible, and mid-facial hypoplasia (Tuxen *et al.*, 2003). Additionally, alterations in the oral mucosa, in the size and shape of the tongue, and in the number, dimensions, shape and arrangement of the teeth can be found (Peretz *et al.*, 1996, 1998; Desai, 1997; Quintanilla *et al.*, 2002). These modifications are obviously

all interrelated: the anterior tongue position has been considered a factor explaining the increased occurrence of a Class III malocclusion with crossbite and anterior open bite found in subjects with Down's syndrome when compared with the general population (Quintanilla *et al.*, 2002). The same mechanical factor may account for the proclination of the anterior mandibular teeth and reduced interincisal angle (Quintanilla *et al.*, 2002).

While both cephalometry and anthropometry have been used for the assessment of the craniofacial characteristics of subjects with Down's syndrome, it has to be underlined that most of the above-mentioned anomalies can be assessed by non-invasive anthropometric measurements. Radiographic analyses have several limitations. They use ionizing radiation, thus being potentially dangerous for the subject's health; they provide a two-dimensional assessment of the skeletal configuration, neglecting most of the soft tissues, and project all structures on a single (usually mid-sagittal) plane (Quintanilla *et al.*, 2002). On ethical grounds, radiographic analyses cannot be performed on healthy subjects without a medical indication. In contrast, anthropometry is a three-dimensional (3D), non-invasive technique, which considers all the facial structures, thus providing a more complete evaluation of the patient (Allanson *et al.*, 1999; Ward *et al.*, 2000; Farkas *et al.*, 2001a, b, 2002a, b; Guyot *et al.*, 2001, 2003; Meintjes *et al.*, 2002; Moore *et al.*, 2002; Zankl *et al.*, 2002; Bagic and Verzak, 2003; Douglas *et al.*, 2003; Zankl and Molinari, 2003). The collection of normative data does not infringe any current ethical consideration.

Recent quantitative studies performed with conventional anthropometry have analysed facial dimensions and ratios in North American white (Farkas *et al.*, 2001a, b, 2002a, b) and Croatian (Bagic and Verzak, 2003) subjects with Down's syndrome. In contrast, no data on 3D facial angles appear to have been published.

The aims of the present investigation were to characterize and quantitatively analyse the facial soft tissues of a group of Italian subjects with Down's syndrome using computerized anthropometry. Facial angles (facial convexity in the horizontal and sagittal planes, nasal convexity, interlabial, nasolabial, mandibular corpus convexity in the horizontal plane, left and right soft tissue gonial angles) were calculated and compared with those of a normal reference population. The analysis was limited to a group of athletes with Down's syndrome attending the Italian games of the Special Olympics, all living with their families, and in good health.

Subjects and methods

Subjects

Data from 28 subjects with Down's syndrome (17 males, 11 females) aged 12–45 years (mean 26.8 years, standard deviation 9 years) were collected (Table 1). All were

white northern Italians, attending the 2003 Italian games of the Special Olympics in Fiuggi (Frosinone). None had undergone craniofacial surgical or orthodontic procedures.

All subjects had permanent central incisors and permanent posterior teeth (premolars and at least one molar), with either natural elements or prostheses. Agenesis of the maxillary lateral incisors was found in M03, M08, M14; agenesis of the upper canines in M14. In subject M01 the permanent maxillary canines were still erupting, while F01 had primary maxillary canines.

Reference data were collected for 429 normal subjects of the same gender, ethnic group and age. Some of this data has been published previously (Ferrario *et al.*, 2003b; Sforza *et al.*, 2003). Each reference group (for each age group and gender) comprised at least 30 subjects. In the reference groups, no subject with a previous history of orthodontic treatment, craniofacial trauma or congenital anomalies was included. For males, four age groups were included: young males (12–14 years), adolescents (15–17 years), young adults (18–30 years) and mid-aged adults (31–45 years). For females, three age groups were included: adolescents (15–17 years), young adults (18–30 years) and mid-aged adults (31–45 years). No selection was made on the basis of dental maxillomandibular relationships (Angle Class of occlusion).

All the analysed individuals, and the parents/legal guardians of the Down's syndrome subjects and all the reference subjects under 18 years of age gave their informed consent to the study. All procedures were non-invasive, did not provoke damage, risk or discomfort to the subjects, and were approved by the local Institutional Review Board.

Collection of the 3D facial landmarks

The data collection procedure took place in two separate stages, followed by off-line calculations (Ferrario *et al.*, 1998, 2003b). First, for each subject, a single experienced operator (CD) located a set of 50 soft tissue landmarks by inspection and/or palpation, and marked them on the cutaneous surface using an eye-liner pencil. During landmark marking, the subjects sat relaxed in a position suitable for correct identification of facial features.

For the second stage, the 3D co-ordinates of the facial landmarks were obtained with a computerized electromechanical digitizer (Microscribe G2, Immersion Corporation, San Jose, California, USA). The instrument is a multijoint-arm digitizer, with an accuracy of 0.38 mm (workspace 50" sphere). Using the instrument's standard tip, a single operator (CD) digitized the marked landmarks according to a standardized sequence devised to reduce data collection time while the subjects sat motionless in the natural head position. Data collection took approximately 1 minute. The files of the 3D (x , y , z) co-ordinates were obtained, and stored on magnetic media.

Computer programs devised and written by one author (VFF) were used for all the subsequent off-line calculations.

Table 1 Three-dimensional soft tissue facial angles (degrees) in the sample of 11 female and 17 male subjects with Down's syndrome.

	Age	t _r -n-t _i	t _r -prn-t _i	t _r -pg-t _i	go _r -pg-go _l	t _r -go _r -pg	t _i -go _l -pg	n-sn-pg	n-prn-pg	sn-n-prn	prn-sn-ls	(sn-ls)-(li-sl)
Females												
F01	15.7	70.1	59.7	55.6	67.2	116.6	120.6	165.6	134.1	20.7	104.4	112.1
F02	15.7	76.0	65.8	59.7	73.0	113.3	113.1	156.4	135.0	15.8	133.4	138.6
F03	22.2	76.7	68.8	64.1	72.8	109.7	118.0	172.5	138.6	23.8	118.3	161.8
F04	22.3	67.8	60.1	59.0	72.9	118.2	111.1	155.6	130.2	20.4	142.2	119.3
F05	24.0	71.8	63.1	58.2	64.7	108.2	112.7	173.9	139.0	23.1	124.6	144.0
F06	27.6	74.9	65.3	60.5	62.0	115.7	118.1	168.4	138.3	18.8	119.2	155.9
F07	27.8	72.2	64.2	62.2	66.9	120.5	110.6	162.1	133.9	19.4	130.5	139.9
F08	31.4	76.5	67.5	61.0	70.0	105.6	99.4	167.1	136.0	23.6	114.7	111.1
F09	35.2	73.7	64.1	61.7	74.6	120.4	113.1	158.3	128.7	22.3	128.9	131.2
F10	35.3	76.6	65.9	61.5	63.3	119.8	120.2	174.1	136.4	28.5	132.8	172.8
F11	45.1	78.3	68.4	64.7	76.3	115.5	105.5	160.8	128.7	24.1	133.6	141.6
Mean	27.5											
SD	8.9											
Males												
M01	12.8	79.7	66.6	59.8	72.9	121.6	119.4	145.3	126.4	16.0	148.1	150.5
M02	13.5	70.0	60.9	58.2	67.0	100.9	90.3	161.8	129.7	23.8	108.2	93.3
M03	15.5	74.9	65.0	58.1	68.9	119.5	117.0	165.9	133.7	24.0	137.5	149.1
M04	16.8	69.8	61.4	58.8	65.8	120.8	111.1	156.1	129.2	21.7	142.6	133.6
M05	20.2	71.5	63.8	60.8	85.1	127.3	120.3	160.8	137.4	16.4	149.3	163.1
M06	20.4	74.0	64.3	60.2	73.0	111.7	111.0	162.8	132.1	23.4	129.5	131.5
M07	20.7	73.9	65.1	58.5	68.7	118.1	117.1	166.8	132.3	26.4	121.2	130.0
M08	22.2	73.6	72.5	64.1	58.6	74.7	112.6	173.6	138.4	24.5	124.0	108.7
M09	26.6	73.4	64.1	59.4	72.8	129.2	111.5	164.7	130.3	26.0	128.2	125.8
M10	30.1	74.4	65.3	60.8	71.9	130.5	117.1	165.3	132.0	23.6	120.7	149.1
M11	32.0	76.9	65.5	56.5	71.8	122.9	114.2	167.2	138.1	19.4	113.0	146.5
M12	33.1	76.8	68.3	62.6	73.8	103.3	107.7	175.1	136.2	31.1	109.1	139.8
M13	33.3	78.0	67.7	60.0	78.1	124.3	116.5	171.0	136.6	24.3	109.6	132.9
M14	34.6	76.3	65.1	61.5	77.1	123.9	128.4	154.2	130.7	18.0	143.7	142.8
M15	35.2	73.7	62.8	55.6	67.6	117.8	112.9	164.0	135.9	21.0	127.8	137.5
M16	40.8	77.1	67.0	67.7	78.6	112.0	112.2	162.0	121.0	30.0	124.8	124.3
M17	41.4	72.2	60.8	56.4	62.4	117.8	116.7	167.1	136.0	19.2	142.9	175.0
Mean	26.4											
SD	9.4											

SD, standard deviation

First, the 3D co-ordinates of the landmarks were used for a fast reconstruction of facial morphology, and an examination of the video image and the face of the subject was performed to assess the correct sequence of landmarks, and any motion artefact. The procedure was repeated immediately, if necessary. In the current group of 28 subjects with Down's syndrome, it was repeated only once.

Among the 50 soft tissue landmarks collected (Ferrario *et al.*, 1998, 2003b), the following were used in the analysis (Figure 1): midline landmarks: n, nasion; prn, pronasale; sn, subnasale; ls, labiale superius; li, labiale inferius; sl, sublabiale; pg, pogonion; paired landmarks (right and left side noted r and l): t_r, t_l, tragon; go_r, go_l, gonion.

The reproducibility of landmark identification and marker positioning have previously been reported, and found to be reliable, with Dahlberg's errors (Bister *et al.*, 2002) on 50 landmarks of 1.20 mm (males) and 0.95 mm (females), corresponding to 1.04 and 1.05 per cent of the relevant nasion-mid-tragon distances (Ferrario *et al.*, 1998). The data collection procedure with the electromechanical instrument was assessed for 10 normal subjects (one female and nine

males aged 20–23 years), and gave a Dahlberg's error of 1.33 mm (1.29 per cent of the relevant nasion-mid-tragon distances). For the analysed angles, the coefficients of variation of repeated digitizations ranged between 0.2 and 4.5 per cent.

Data analysis

According to the geometric models of the face defined by Ferrario *et al.* (1998, 2003b), the x, y, and z co-ordinates of the landmarks obtained for each subject were used to calculate the following facial angles: facial convexity in the horizontal plane (upper facial convexity, t_r-n-t_l, middle facial convexity including the nose, t_r-prn-t_l, and lower facial convexity, t_r-pg-t_l); mandibular corpus convexity in the horizontal plane (go_r-pg-go_l); facial convexity including the nose (n-prn-pg); facial convexity excluding the nose (n-sn-pg); interlabial angle (sn-ls)-(li-sl); nasolabial angle (prn-sn-ls); angle of nasal convexity (sn-n-prn); left and right soft tissue gonial angles (t_l-go_l-pg, t_r-go_r-pg).

For the 429 reference, normal subjects, descriptive statistics were calculated for each variable separately for

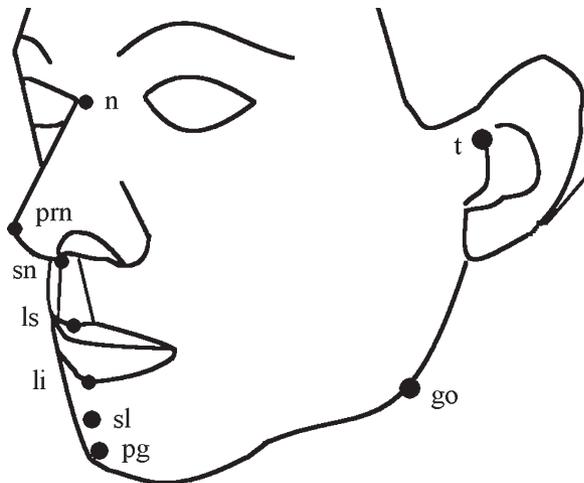


Figure 1 Soft tissue facial landmarks digitized on all subjects: midline landmarks: n, nasion; prn, pronasale; sn, subnasale; ls, labiale superius; li, labiale inferius; sl, sublabiale; pg, pogonion; paired landmarks: t, tragion; go, gonion.

each age group and gender using the rectangular components of the angles. The individual measurements obtained in the 28 subjects with Down's syndrome were transformed to z -scores by subtracting each from its gender and age reference mean value, and dividing by the relevant reference standard deviation (Allanson *et al.*, 1998; Ward *et al.*, 2000; Guyot *et al.*, 2001; Farkas *et al.*, 2001a, b, 2002a, b; Moore *et al.*, 2002).

Statistical calculations

Descriptive statistics (mean and standard deviation) were computed for the values of the 11 z -scores separately for males and females, 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 the angles in the Down's syndrome subjects do not differ from the reference population; alternative hypothesis: z -scores significantly different from zero), and unpaired Student's t -tests (null hypothesis: male values do not differ from female values; alternative hypothesis: male values are different from female values). Correlation analyses were also performed between age and the 11 z -scores. For all analyses, a P -value of 0.05 or smaller was considered significant.

Results

Table 1 reports the 3D facial angles computed in the analysed subjects. Male and female subjects had similar mean ages ($P > 0.05$, Student's t -test for independent samples, 26 degrees of freedom).

For each measurement, z -scores were obtained by subtracting each individual value from its gender and age reference mean value, and dividing by the relevant reference

standard deviation. No significant gender-related differences were found for the analysed z -scores (Student's t -test, $P > 0.05$ for all 11 z -scores), and pooled values were computed (Table 2). Seven of the 11 z -scores were significantly different from zero (paired Student's t -test, $P < 0.05$, 27 degrees of freedom).

Overall, facial convexity in the horizontal plane (both in the upper and middle facial third), facial convexity in the sagittal plane (both including and excluding the nose) and the angle of nasal convexity were significantly increased (flatter) in subjects with Down's syndrome than in their normal controls selected for gender, age and ethnicity (positive z -scores).

Both left and right soft tissue gonial angles were significantly reduced (more acute) in the analysed subjects with Down's syndrome than in the normal controls. Additionally, negative (but not significant) mean z -scores were found for lower facial convexity and mandibular corpus convexity in the horizontal plane, and for interlabial and nasolabial angles.

In the pooled sample, no statistically significant correlations between age and the 11 z -scores were found ($P > 0.05$).

As an example, the soft tissue facial features of a subject with Down's syndrome, a young female aged 24 years, as compared with her gender- and age-related normal reference group are depicted in Figure 2 (frontal view) and Figure 3 (lateral view).

Discussion

Craniofacial morphology in subjects with Down's syndrome has been investigated using both radiographic and anthropometric methods (Farkas *et al.*, 2001a, b, 2002a, b; Richtsmeier *et al.*, 2002; Bagic and Verzak, 2003). Whereas the use of radiographs only allows the assessment of the underlying skeletal morphology, anthropometry permits a 3D study of the entire craniofacial arrangement without submitting the subject to potentially harmful procedures. Data can be easily compared with that of healthy subjects of the same age, gender, race and ethnic group (Farkas *et al.*, 2001a, b, 2002a, b).

Current technology provides several instruments that can be used for indirect anthropometric assessments (Papadopoulos *et al.*, 2002; Ferrario *et al.*, 2003a; Guyot *et al.*, 2003). Recent comparisons between conventional anthropometry and digital data have demonstrated reliable values and non-significant differences (Meintjes *et al.*, 2002; Guyot *et al.*, 2003; Sforza *et al.*, 2004).

The method used in the current study allows the direct digitization of single facial landmarks that are individualized using the same criteria of conventional anthropometry. The co-ordinates of the landmarks are then used for off-line calculation of distances and angles (Ferrario *et al.*, 1998). New measurements can be assessed starting from the same landmarks without the need for a new data collection

Table 2 Descriptive statistics of the z-score values of the analysed facial angles (males plus females).

	t_r-n-t_l	$t_r-prn-t_l$	t_r-pg-t_l	$go_r-pg-go_l$	t_r-go_r-pg	t_l-go_l-pg	$n-sn-pg$	$n-prn-pg$	$sn-n-prn$	$prn-sn-ls$	$(sn-ls)-(li-sl)$
Mean	1.022	1.469	-0.040	-0.313	-1.082	-1.387	0.637	1.179	0.583	-0.147	-0.398
Standard deviation	1.126	1.377	1.317	1.308	2.155	1.529	1.025	1.306	1.402	1.773	1.292
<i>P</i>	0.001	0.001	NS	NS	0.015	0.001	0.003	0.001	0.040	NS	NS

P, Student's *t*-test for paired samples (27 degrees of freedom); NS, not significant ($P > 0.05$).

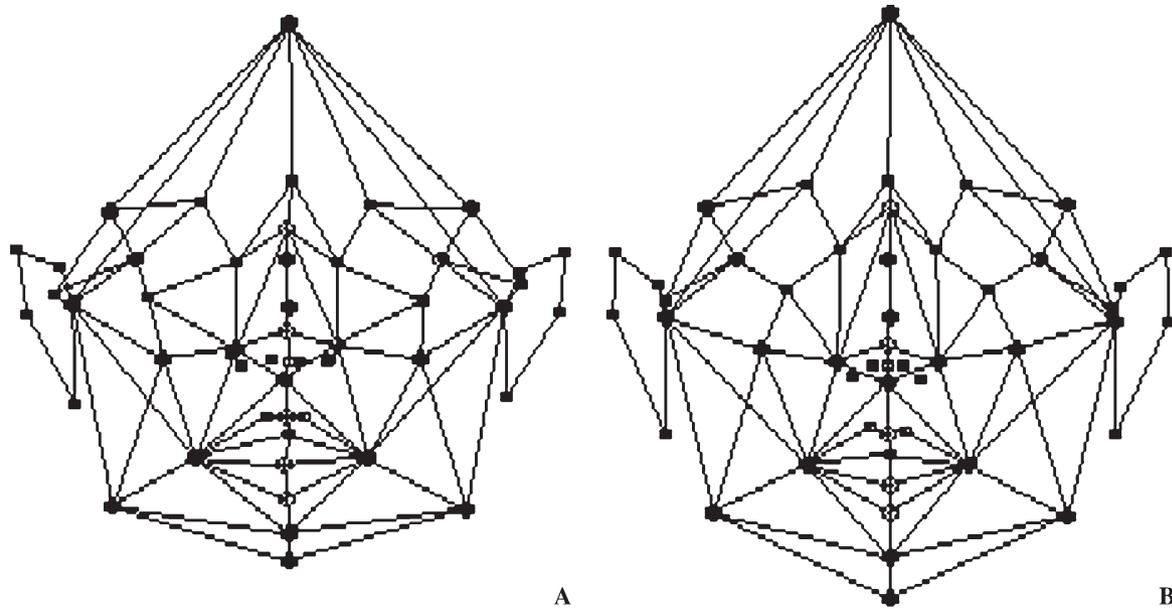


Figure 2 A schematic diagram of the three-dimensional frontal view of the facial landmarks of a 24-year-old female with Down's syndrome (A) and of her gender- and age-related normal reference group (B).

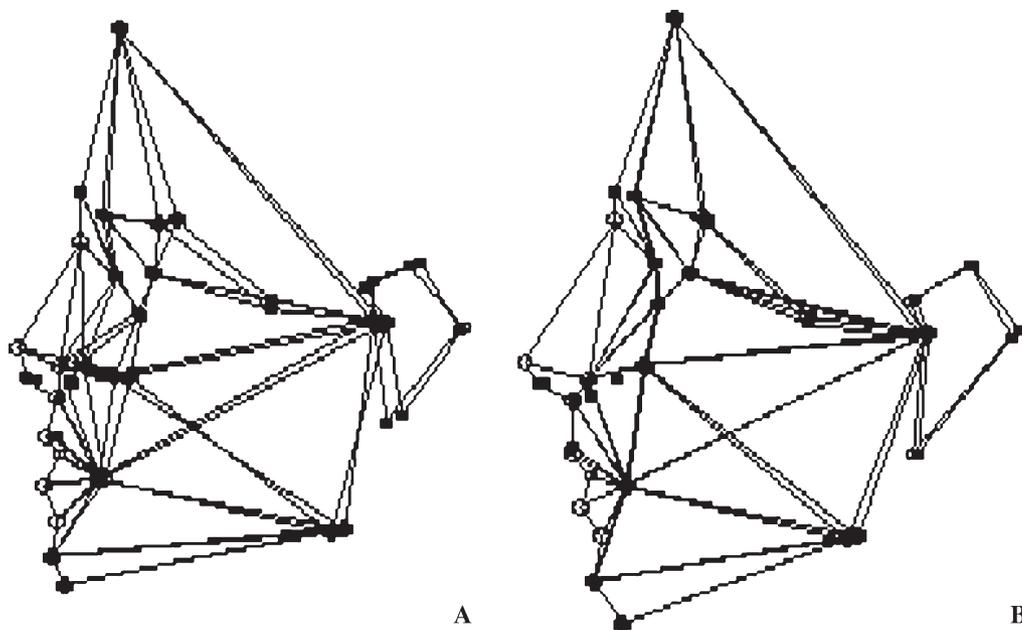


Figure 3 A schematic diagram of the three-dimensional lateral view of the facial landmarks of a 24-year-old female with Down's syndrome (A) and of her gender- and age-related normal reference group (B).

session (Ferrario *et al.*, 1998). Overall, the method appears faster and simpler than the conventional procedure (Bagic and Verzak, 2003), and particularly suitable for subjects with a disability.

Optical instruments (laser scanners, 3D range cameras, stereophotogrammetry) can also be used for a fast analysis of the facial surface, and for indirect anthropometric assessments (Coward *et al.*, 2000; Duffy *et al.*, 2000; Meintjes *et al.*, 2002; Douglas *et al.*, 2003; Yip *et al.*, 2004). These instruments provide a detailed analysis of facial characteristics based on a wealth of soft tissue points but do not assess single anatomical landmarks. The lack of a direct identification of cutaneous landmarks is one of the main limitations of these methods, the landmarks of interest are recognized only on the digitized reconstructions of the face, with some loss of precision [see Ferrario *et al.* (1998) for a detailed discussion]. Nevertheless, in the near future they may prove suitable for anthropometric data collection (Kau *et al.*, 2003).

Individuals with Down's syndrome possess a unique and immediately recognizable craniofacial aspect (Richtsmeier *et al.*, 2000, 2002), but a correct assessment of their morphology should be substantiated by quantitative evaluation (Farkas *et al.*, 2001a, b, 2002a, b; Bagic and Verzak, 2003). Data collected for the present group of subjects with Down's syndrome were compared with those obtained for normal subjects of the same age group, gender and ethnicity by using *z*-scores. The method allows standardization of single measurements obtained from individuals of different ages and genders, and comparison of equivalent values (Ward *et al.*, 2000; Farkas *et al.*, 2001a, b, 2002a, b; Moore *et al.*, 2002).

Chronological age was used for matching the subjects with Down's syndrome and the reference subjects: this procedure may not be the most appropriate considering the variations in growth velocity found with this syndrome (Myrelid *et al.*, 2002; Kimura *et al.*, 2003). During childhood, Down's syndrome children grow slower than normal children (Myrelid *et al.*, 2002), even when subjects with complications that might affect natural growth are excluded (Kimura *et al.*, 2003). Their pubertal growth spurt is usually anticipated, and it has a smaller peak (Myrelid *et al.*, 2002; Kimura *et al.*, 2003). In these subjects, puberty and ageing take place earlier than in the normal population (Roizen and Patterson, 2003): craniofacial morphology may also be affected by these complex alterations, thus making simple matching with chronological age incorrect.

Unfortunately, data on skeletal age or pubertal maturation could not be collected as the subjects with Down's syndrome were all measured outside a clinical, medical setting. The only data on general body growth were standing height and body mass, but they may both be misleading in the assessment of maturity. For instance, Farkas *et al.* (2002b) found that between 6 and 15 years of age 70.6 per cent of

their children with Down's syndrome were of normal height. In adolescence and adulthood, Down's syndrome subjects are predisposed to being overweight (Myrelid *et al.*, 2002; Styles *et al.*, 2002; Roizen and Patterson, 2003), and their body mass cannot be directly compared with that of normal subjects. Therefore, the present results, with *z*-scores calculated with chronological age, should be interpreted with caution. Nevertheless, all recent anthropometric studies have used the same matching (Farkas *et al.*, 2001a, b, 2002a, b; Bagic and Verzak, 2003).

Overall, the present results were in good agreement with findings reported in the literature: a hypoplastic facial middle third with reduced nasal protrusion (a flatter facial convexity in both the horizontal and sagittal planes, including the nose), and a reduced mandibular region (reduction in both left and right soft tissue gonial angles) (Desai, 1997; Richtsmeier *et al.*, 2000, 2002; Farkas *et al.*, 2001a, b, 2002a, b; Quintanilla *et al.*, 2002; Bagic and Verzak, 2003; Roizen and Patterson, 2003; Tuxen *et al.*, 2003). A tendency for a prominent mandible was also noted, with a non-significant reduction in the mandibular corpus convexity in the horizontal plane.

Prominent lips were also found, and 17 of the 28 subjects with Down's syndrome had a reduced interlabial angle. This finding is in accord with the reduction in the interincisal angle reported by Quintanilla *et al.* (2002). Thirteen subjects had a more acute nasolabial angle. Unfortunately, interindividual variability for these measurements was large, and prevented the assessment of statistical significance. An increased individual variability in Down's syndrome subjects has already been reported (Richtsmeier *et al.*, 2000): the phenotypic variations may be an effect of the underlying genotypic differences (Tuxen *et al.*, 2003).

The number and position of teeth has not been reported in previous investigations. Modifications in dental support (maxillary anterior teeth) to the soft tissue structures (Perkins and Staley, 1993) may explain the variations in the position of the upper lip: the *z*-scores of the interlabial angle ranged between -2.4 and 2.2, and those of the nasolabial angle between -6.5 and 2.2.

The present results cannot be completely compared with reports on Down's syndrome subjects because not only has no data on 3D facial angles been reported so far, but no information on the faces of Italian 'white' subjects seems to exist. Ethnic variations in the facial morphology of Down's syndrome subjects have already been described (Farkas *et al.*, 2001a, b; Bagic and Verzak, 2003; Cicero *et al.*, 2003; Sonek, 2003).

In the present study, no significant differences between the *z*-scores computed for the male and female subjects were found, in agreement with Bagic and Verzak (2003). Additionally, no significant age-related differences in the pooled *z*-scores were observed: the *z*-scores were not influenced by age. This finding may be an indirect result of the lack of major errors in using chronological age for comparisons: for the analysed 3D

angles, and in the present group of Down's subjects, the deviation from normality was independent of age.

On the issue of age-related changes, there seems to be no agreement in the literature. Whereas Farkas *et al.* (2002a) found that alterations in craniofacial morphology in Down's syndrome subjects tended to lessen after maturation, suggesting a positive effect of growth and development on this genetically determined abnormal anatomy, contrasting data were reported by Bagic and Verzak (2003). Ethnic variations may partly explain these different findings.

The number of Down's subjects investigated was limited as the data were collected only from athletes competing at the Italian session of the Special Olympics. This group lived with their families and were in good health. In contrast, Bagic and Verzak (2003) mainly analysed subjects living in residential institutions. Currently, the effects of a different quality of life on the craniofacial morphology of subjects with aneuploidy are unknown. Nevertheless, given the increasing number of subjects with Down's syndrome living in the community (Roizen and Patterson, 2003), the assessment of the characteristics of these persons may be of help to clinicians and basic researchers. The use of this highly selected group of Down's subjects is a limitation of the current study as the results cannot automatically be extended to all subjects with Down's syndrome.

Conclusion

Computerized anthropometry can be used for the quantitative examination of the facial characteristics of subjects with Down's syndrome. Accurate digitization of facial landmarks can be performed in a very short period of time and without potentially harmful procedures.

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