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Forensic Anthropology Population Data

Age- and sex-related changes in three-dimensional lip morphology

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ABSTRACT

The objective of this study was to supply information about: (1) normal sex-related dimensions of mouth and lips (linear distances, ratios, angles, area, volume); and (2) growth changes between childhood and old age. The three-dimensional coordinates of several soft-tissue landmarks on the lips and face were obtained by a non-invasive, computerized electromagnetic digitizer in 532 male and 386 female healthy subjects aged 4–73 years. From the landmarks, linear distances (mouth width, width of the philtrum, vermilion heights of the upper, lower and total lips, total lip height), the vermilion height-to-mouth width ratio, areas (vermilion of the upper, lower and total lip) and volumes (upper, lower, and total lip volume) were calculated and averaged for age and sex. Comparisons were performed by factorial analysis of variance. Mouth width, width of the philtrum, total lip height, and lip volumes were significantly larger in men than in women ($p < 0.01$), increased with age ($p < 0.001$), and had age $\times$ sex interactions ($p < 0.001$). Vermilion areas and heights of the lower and total lips progressively increased with age until late adolescence, and then decreased with aging ($p < 0.001$). The vermilion height-to-mouth width ratio was larger in women than in men ($p < 0.001$), and decreased with age ($p < 0.001$). Data collected in the present investigation could serve as a database for the quantitative description of human lip morphology during normal growth, development and aging. Forensic applications (evaluations of traumas, craniofacial alterations, teratogenic-induced conditions, facial reconstruction, aging of living and dead persons, personal identification) may also benefit from age- and sex-based data banks.

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1. Introduction

The face characterizes human beings, and in everyday life personal identification is mostly made by facial assessment [1–3]. In particular, the mouth and lips plays a key role in the evaluation and recognition of the craniofacial complex.

After child and adolescent growth and development, all parts of the face continue to modify during adulthood, even after the attainment of biological maturity [4–19]. Sex- and age-related variations in the orolabial region are particularly important also considering the functional, social and esthetic role played by the facial soft tissues [10,12–14,16,20–22].

Apart from anatomical and anthropometric descriptions, knowledge of the age- and sex-related qualitative and quantitative normal characteristics of the mouth and lips may provide useful information in several medical fields. For instance, reference data are necessary to surgeons and orthodontists treating dentofacial deformities: diagnosis and treatment should obtain harmonious facial characteristics concurring to a sound functionality [13,16,17,20,23–27].

In contemporary western society, not only are the number of aged persons increasing, but also clinical treatments (surgical, medical, dental) and forensic investigations are currently being requested by people with a wider age range than before, thus needing new reference data, that should be collected on each ethnic group.

The definition of age-, sex- and ethnic-specific databases may help in the identification of those individual features that best discriminate among persons [1,2]. Also, there is an urgent need for age-related facial dimensions that may help in the aging of victims from pedo-pornography [28].

Facial reconstructions also need data collected from living persons of the widest possible age span, supplying information that may assist in simulating the modifications of facial features during normal growth and aging [6,13,16,29].

Previous investigations quantitatively analyzed the age and sex characteristics of the orolabial region, assessing both dimensions, reciprocal spatial positions, and relative proportions [7–11,14–16,24,26,30–32]. Assessments had been performed both with two-dimensional photographic and radiographic records and three-dimensional direct and indirect (digital) anthropometry. In particular, current technology provides various image analysis systems that work in the three-dimensional space (range-camera techniques, stereophotogrammetry, laser scanning, optoelectronic

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systems, electromagnetic three-dimensional digitizers), and that supply non-invasively the digital coordinates of the landmarks of interest [3,8,11,12,18,19,21,23–25,27,30–36].

Aging particularly affects the lips, with reductions in thickness, and in vermilion dimensions, coupled with increments in the distance between the nose and the upper lip vermilion border, and in mouth width [10,12–14,16,27].

Overall, quantitative data on the postnatal growth, development and aging of the lips and mouth have been provided only for limited age ranges: Mamandras [4,5] longitudinally followed up subjects between 8 and 18 years of age; Farkas et al. [7] analyzed subjects between birth and 25 years of age; Ferrario et al. [8] studied children and adolescents aged 6–18 years of age; Mori et al. [24] measured children aged 5–6 years; Zhu et al. [15] analyzed children aged 2–12 years. Two- and three-dimensional data on adult and aging subjects were provided by Caisey et al. [14], Ferrario et al. [31], Iblher et al. [16], Lévêque and Goubanova [12], Ozdemir et al. [26] and Sawyer et al. [27]; additionally, Akgül and Toygar [10] longitudinally followed up adult subjects between 22 and 32 years of age.

In particular, three-dimensional, quantitative data about normal subjects after the third-fourth decades of life into old age are still incomplete, and only mouth width and vermilion height were measured until 80 years of age [12].

In the current study, information about normal sex-related dimensions (linear distances, areas and volumes) of the mouth and lips between childhood and old age, were provided. Data were collected non-invasively using digital anthropometry in healthy Italian Caucasians aged 4–73 years.

2. Materials and methods

2.1. Subjects

Data on 918 healthy white Italians aged 4–73 years were collected. The subjects were divided into several non-overlapping age groups: for subjects younger than 18 years, 2-year spans were used, while larger intervals were used for adult subjects [18,19].

Subjects with a previous history of craniofacial trauma, congenital anomalies or surgery were not included in the sample. Participants were informed about all the adopted procedures, and gave their consent to the investigation. Informed consent was also obtained from the parents/legal guardians of the subjects underage. The study protocol was approved by the local ethic committee. All procedures were not invasive, not potentially harmful, did not provoke pain and did not use any instrument or energy currently considered to be potentially dangerous to the present or future health of the subjects or of their offspring.

2.2. Collection of three-dimensional facial landmarks

The data collection procedure was previously described in detail [11,18,19,21,23,25,30]. In brief, for each subject, a single experienced operator located a set of 50 landmarks and marked them on the cutaneous surface. During landmark marking, the subjects sat relaxed with a natural head position. The complete set of 50 landmarks allowed the quantitative study of head, face, orbits, nose, lips and mouth, ears in the living human subjects [11].

Three-dimensional (x, y, z) coordinates of the facial landmarks were obtained with a three-dimensional computerized electromagnetic digitizer (3Draw, Polhemus Inc., Colchester, VT). The system has an accuracy of 0.25 mm, a resolution of 0.13 mm/mm of range, and it supplies actual metric data independent from external reference systems. Digitization of landmarks was performed by a single operator.

In the present study, from the complete set of 50 landmarks the following soft tissue landmarks were further considered (Fig. 1).

- midline landmarks: sn, subnasale; ls, labiale superius; sto, stomion; li, labiale inferius; sl, sublabiale;
- paired landmarks (right and left side noted r and l): cph_r, cph_l, crista philtri; ch_r, ch_l, cheilion.

The reproducibility of landmark identification and marker positioning were previously reported, and found to be reliable, with Dahlberg's errors on 50 landmarks of 1.20 mm (males) and 0.95 mm (females), corresponding to 1.04 and 1.05% of the relevant nasion-mid tragion distances [30].

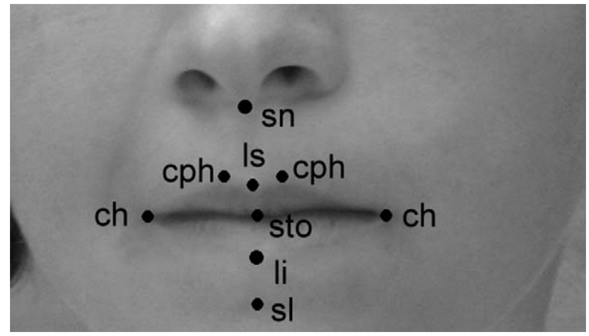

Fig. 1. Digitized three-dimensional labial landmarks used in the current study (sn, subnasale; ls, labiale superius; sto, stomion; li, labiale inferius; sl, sublabiale; cph, crista philtri; ch, cheilion).

2.3. Data analysis

According to the geometric model of the lips and nose defined by Ferrario et al. [8,23,31], the x, y, z coordinates of the landmarks obtained on each subject were used to calculate the following parameters:

- linear distances (unit: mm): mouth width (ch_r-ch_l); width of the philtrum (cph_r-cph_l); vermilion height of the upper lip (ls-sto); vermilion height of the lower lip (sto-li); total vermilion height (ls-li); total (cutaneous) lip height (sn-sl);
- ratio (unit: %): vermilion height to mouth width (ls-li/ch-ch) $\times$ 100;
- areas (unit: mm^2): vermilion of the upper lip (area of the quadrangle between ch_r, ls, ch_l, sto); vermilion of the lower lip (area of the quadrangle between ch_r, li, ch_l, sto); total vermilion (area of the quadrangle between ch_r, ls, ch_l, li);
- volumes (unit: mm^3): upper lip volume (approximated from the volumes of two tetrahedra: the first tetrahedron had the plane ch_r, ch_l, ls as its base and vertex in sn, the second had the plane ch_r, ch_l, ls as its base and vertex in sto); lower lip volume (as above, first tetrahedron with the plane ch_r, ch_l, li as its base and vertex in sl, the second with the plane ch_r, ch_l, li as its base and vertex in sto); total lip volume (sum of the four tetrahedra).

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

Descriptive statistics (mean and standard deviation) for each measurement were computed within sex and age group.

Mean values between sexes and age groups were compared using two-way factorial analyses of variance. The effect of sex (factor 1 of the analysis of variance), and the effect of age (factor 2 of the analysis of variance) were assessed, as well as the sex $\times$ age interaction. Significance was set at 5% ($p \leq 0.05$), with two-tail statistical tests used in all analyses.

The age-related variations of selected measurements were assessed by polynomial (fourth degree) regression analyses; calculations were performed by grouping the subjects by sex and age group; the percentage of explained variance was also assessed as R^2 (coefficient of determination).

3. Results

All labial volumes and total lip area were larger in men than in women (Tables 1–3). A significant sexual dimorphism was found also for mouth and philtrum widths, and total lip height (all larger in men than in women), as well as for the vermilion height to mouth width ratio (larger in girls than in boys, in adolescent boys than in girls, and in women than in men).

All measurements significantly modified as a function of age, with significant age $\times$ sex interactions. Mouth width and lip volumes increased with age; their age-related modifications were larger during childhood and adolescence than during adulthood, and were well described by 4th order polynomial regressions, that explained between 86 and 96% of the relevant variance (Table 4 and Figs. 2 and 3). Total lip height increased with age, and after young adulthood its values remained nearly stable (Fig. 4). Also philtrum width increased with age, but its age-related modifications were more scattered, and the polynomial equations explained only 64% (men) and 69% (women) of the variance. Vermilion areas and heights of the lower and total lips

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