# Stereophotogrammetric analysis of labial morphology in a young adult Middle-Eastern population

Fouad Ayoub [a], Maria Saadeh [a, b, c, *], Hasan Fayyad-Kazan [d], Ramzi Haddad [c]

[a] Department of Forensic Odontostomatology and Human Identification, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon
[b] Department of Orthodontics, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon
[c] Division of Orthodontics and Dentofacial Orthopedics, American University of Beirut Medical Center, Beirut, Lebanon
[d] Department of Basic Sciences, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon

## A R T I C L E   I N F O

## A B S T R A C T

*Introduction:* The majority of previous research delineating the morphological characteristics of the orolabial region has been on Caucasian populations, with very minor research on Mediterranean populations, and none on the Lebanese population.
*Aim:* The primary aim was to collect information on the gender-specific 3D morphology of the mouth and lips in young Middle Eastern adults. The secondary aim was to explore the presence of associations between orolabial morphology and age and body mass index (BMI), and to assess correlations between linear orolabial dimensions and area/volume measures.
*Methods:* The study used non-invasive stereophotogrammetry to collect information on gender-specific 3D labial morphology (linear distances, areas, and volumes) for 122 adult Lebanese subjects, aged 18–30 years (47 males, 75 females). Associations between labial morphology and age and body mass index were assessed, in addition to correlations between linear orolabial dimensions and area/volume measures.
*Results:* All linear, angular, area, and volume lip measurements displayed significant variability. Both lip area and volume were smaller in the upper than in the lower lip. Eighteen out of the 20 linear measurements were significantly larger in males. The ratio, area, and volume measurements mostly displayed no statistically significant gender dimorphism.
*Conclusions:* Alongside presenting the first documented report on anthropometric labial measurements of a young Lebanese adult population, this research highlights the presence of gender dimorphism in linear and angular measurements, but not in area and volume measurements, and a strong association between certain linear labial measurements and lip area and volume. In addition, it presents pilot data on the association between labial anthropometry and body mass index.
© 2018 European Association for Cranio-Maxillo-Facial Surgery. Published by Elsevier Ltd. All rights reserved.

## 1. Introduction

The human face plays a vital role in interpersonal communication, individual identification, and in portraying the underlying health of the individual, and therefore has historically received much interest from artists and scientists alike (Hennessy et al., 2005; Tollefson and Sykes, 2007; Kochel et al., 2010; Mutsvangwa et al., 2010, 2011; Sforza and Ferrario, 2010; Smeets et al., 2010; Fang et al., 2011; Ritz-Timme et al., 2011; Verze et al., 2011). The mouth and lips, in particular, play an important role in the evaluation and recognition of the craniofacial complex (Sforza et al., 2010).

Existing research on the morphology of the orolabial region highlights the variability of the lips between genders (Ferrario et al., 2000; Sawyer et al., 2009; Sforza et al., 2010; Al-Khatib et al., 2012) in addition to the effects of age (Sforza et al., 2010, 2016). These features underscore the importance of reference databases on lip morphology in providing essential information for personal identification and/or discrimination between persons (Sforza et al., 2010), an area of study with a variety of applications in the fields of forensics, criminology, and medicine (Aeria et al., 2010; Smeets et al., 2010; Arca et al., 2012). Practical forensic applications include facial reconstruction from skeletal remains, age estimation

of living individuals, and artificial aging of facial records of missing children (De Greef et al., 2006; Cattaneo et al., 2009; Claes et al., 2010; Wilkinson, 2010; Ritz-Timme et al., 2011; Hwang et al., 2012; Lee et al., 2012). Additionally, the dimensions, spatial positions, and relative proportions of the structures in the nasolabial region are integral to diagnosis and treatment planning for patients in orthodontic, maxillofacial, and plastic surgery settings (Mack, 1991; Lundström et al., 1992; Skinazi et al., 1994; Ferrario and Sforza, 1997).

The majority of previous research delineating the morphological characteristics of the orolabial region has been on Caucasian populations (Ferrario et al., 1999; Fernández-Riveiro et al., 2003; Sforza and Ferrario, 2010; Sforza et al., 2011; Möller et al., 2012; Vahdettin and Altuğ, 2012), with a considerable amount also on Chinese subjects (Dong et al., 2010; Jayaratne et al., 2014; Li et al., 2014). Assessment methodologies have included two-dimensional photography and radiography, direct anthropometry, and three-dimensional (3D) digital anthropometry (Sforza et al., 2013). Amid the various advances in digital anthropometry (computed tomography, magnetic resonance imaging, laser scanning), stereophotogrammetry is a safe, radiation-free, and non-invasive method that retrieves excellent-quality 3D photographs of the face (Sforza et al., 2013).

To our knowledge, the only assessment of lip morphology in the Middle East and North African region has been on the Sudanese population (Sforza et al., 2010), with no investigations being performed on Mediterranean populations, including the Lebanese one. Although an Arab country, Sudan's ethnic makeup is reflective of its geographical location in North Africa, and is ethnically distinct from Middle Eastern populations. Moreover, compelling genomic research highlights the predominance of non-Arab Canaanite ancestry (specifically Bronze-Age Phoenician) in the present-day Lebanese population (Haber et al., 2017), thereby reinforcing the importance of population-specific investigations in the Arab region.

The primary aim of this study was therefore to collect information on gender-specific 3D morphology (linear distances, areas, and volumes) of the mouth and lips in young Lebanese adults using digital anthropometry. A secondary aim was to explore the presence of associations between orolabial morphology and age and body mass index (BMI), and also to assess correlations between linear orolabial dimensions and area/volume measures.

## 2. Materials and methods

### 2.1. Study population

This cross-sectional study assessed 122 adult Lebanese subjects (47 males, 75 females), of mean age 23.2 ± 2.8 years (range 18.10–30.0 years) who were selected from the database of patients attending the Lebanese University. Inclusion criteria were as follows: non-growing subject (age > 16 years for females and >18 years for males); balanced profile; class I molar and canine relationships; and normal overjet and overbite (2 ± 2 mm). Subjects with craniofacial anomalies, and history of orthodontic treatment and/or surgical treatment involving the head and neck were excluded. The study was approved by the Institutional Review Board (CUEMB 36/AA) and patients provided written, informed consent.

### 2.2. Imaging system

Vectra® M3 3D imaging for the face and neck captures 3D stereophotogrammetry images of the surface shape, contour, and color of the face, with 1.2 mm geometrical resolution and a capture time of 3.5 milliseconds (Vectra M3, Canfield Scientific Inc, USA). The system consists of six mounted digital cameras, a calibration kit, and a computer.

### 2.3. Collection of 3D facial landmarks

Subjects were seated in natural head position on an adjustable stool facing the Vectra system. All jewelry and makeup were removed, and the hair was secured away from the face, ears, and neck. The patient was then positioned according to system guidelines: 1) patient and stool were moved closer or further away until the patient's eyes were centered between the vertical lines in each of the two side preview images; 2) the position of the face in the right preview window mirrored the position in the left preview window; 3) the stool was lowered or raised until the patient's eyes were centered between the horizontal lines in the center preview image.

The patient was asked to gently close his/her mouth and remain in a neutral expression. The image was then captured and automatically processed to create the 3D model, which was stored as a file on the Vectra computer and displayed on the screen. Images were then imported into the Mirror® software, which was used to locate all relevant nasolabial landmarks (Fig. 1). The Canfield Mirror imaging software was then used to measure the linear, angular, area, and volume measurements (Table 1).

#### 2.3.1. Statistical analysis

Descriptive statistics were generated for all labial measurements for the entire sample and in males and females separately. The Shapiro–Wilk test of normality confirmed that the data were normally distributed ($p > 0.05$). Independent $t$-tests were carried out to evaluate differences in labial morphology between genders.
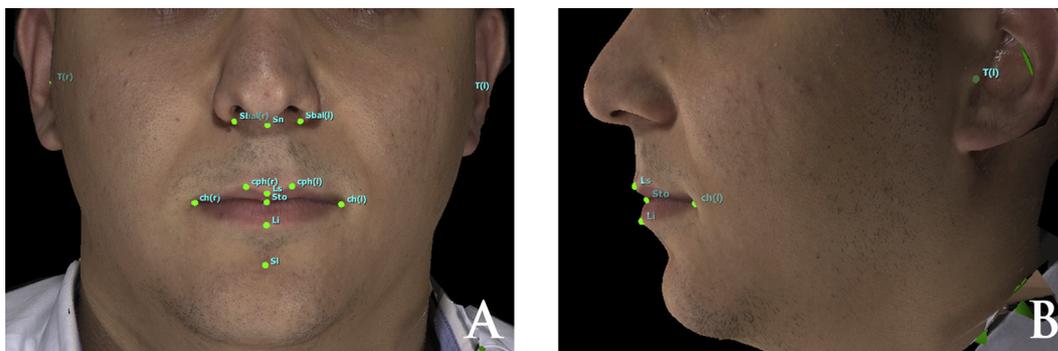


**Fig. 1.** Facial landmarks used in the study in frontal (A) and lateral (B) views. Midline landmarks: subnasale (Sn); labiale superius (Ls); stomion (Sto); labiale inferius (Li); sublabiale (Sl). Bilateral landmarks designated (r) for right and (l) for left: subalare (Sbal); crista philtri (cph); chelion (ch); tragion (T).

**Table 1**
Lip morphology measurement abbreviations and definition.

| Abbreviation | Description |
|---|---|
| *Linear lip measurements* | |
| Cph-Cph | Width of philtrum |
| Chr-Chl | Width of mouth |
| Sn-Sto | Total height of upper lip |
| Sn-Ls | Height of cutaneous upper lip |
| Ls-Sto | Vermilion height of upper lip |
| Li-Sl | Height of cutaneous lower lip |
| Sto-sl | Total height of lower lip |
| Sto-li | Vermilion height of lower lip |
| Ls-Li | Total vermilion height of both lips |
| Sn-Sl | Total cutaneous height of both lips |
| Ch-ls-ch = ch-Ur-Cph-Ls-Cph-Ul-ch | Vermilion surface arc of upper lip |
| Ch-li-ch = Ch-L(l)-LL(l)-Li-LL(r)-L(r)-Ch | Vermilion surface arc of lower lip |
| Ch(r)-Sto | Right labial fissure half width |
| Ch(l)-Sto | Left labial fissure half width |
| Sbal(r)-Ls | Right lateral lip height |
| Sbal(l)-Ls | Left lateral lip height |
| Sbal(r)-Cph(r) | Right upper lip lateral height |
| Sbal(l)-Cph(l) | Left upper lip lateral height |
| Ch(r)-Cph(r) | Right length from crest of philtrum to commissure |
| Ch(l)-Cph(l) | Left length from crest of philtrum to commissure |
| Ch(r)-T(r) | Right labiotragal distance |
| Ch(l)-T(l) | Left labiotragal distance |
| *Angular lip measurements* | |
| UL inclin | Inclination of upper lip |
| LL inclin | Inclination of lower lip |
| Lab-ment ang | Labiomental angle |
| *Area/volume/ratio lip measurements* | |
| Ls-Li/Ch-Ch | Ratio (%) of total lip vermilion height to width |
| Ch(r)-ls-Ch(l)-sto | Upper lip vermilion area |
| Ch(r)-li-Ch(l)-sto | Lower lip vermilion area |
| Ch(r)-ls-Ch(l)-li | Total lip vermilion area |
| UL vol | Upper lip volume |
| LL vol | Lower lip volume |
| Tot lip volume | Total lip volume |

*Notes.* Linear lip measurements recorded in mm, angular lip measurements in degrees, lip area measurements in mm$^2$, and lip volume measurements in mm$^3$.

**Table 2**
Descriptive statistics for age, body mass index (BMI), and lip morphology in assessed Lebanese sample (n = 122).

| | Descriptive statistics | | | |
|---|---|---|---|---|
| | Minimum | Maximum | Mean | SD |
| *Background characteristics* | | | | |
| Age | 18.10 | 29.95 | 23.16 | 2.79 |
| BMI | 17.24 | 33.22 | 22.59 | 3.17 |
| *Linear lip measurements* | | | | |
| Cph-Cph | 5.42 | 16.75 | 11.62 | 2.19 |
| Chr-Chl | 41.89 | 60.79 | 50.56 | 3.46 |
| Sn-Sto | 17.63 | 30.25 | 22.97 | 2.69 |
| Sn-Ls | 10.44 | 29.93 | 16.22 | 3.38 |
| Ls-Sto | 4.16 | 12.05 | 7.89 | 1.66 |
| Li-Sl | 5.67 | 24.29 | 12.93 | 3.13 |
| Sto-sl | 12.65 | 27.21 | 20.02 | 2.62 |
| Sto-li | 2.30 | 14.48 | 8.71 | 2.17 |
| Ls-Li | 6.72 | 24.29 | 15.26 | 3.36 |
| Sn-Sl | 30.28 | 55.17 | 42.79 | 4.48 |
| UL verm S arc | 57.08 | 84.96 | 69.48 | 5.01 |
| LL verm S arc | 51.99 | 82.70 | 64.74 | 5.49 |
| Ch(r)-Sto | 18.66 | 35.74 | 28.17 | 2.51 |
| Ch(l)-Sto | 23.28 | 36.03 | 29.08 | 2.47 |
| Sbal(r)-Ls | 14.02 | 33.27 | 21.23 | 3.60 |
| Sbal(l)-Ls | 15.18 | 34.81 | 21.67 | 3.63 |
| Sbal(r)-Cph(r) | 12.13 | 25.74 | 17.99 | 3.20 |
| Sbal(l)-Cph(l) | 12.67 | 26.21 | 18.16 | 3.08 |
| Ch(r)-Cph(r) | 20.08 | 32.78 | 27.49 | 2.41 |
| Ch(l)-Cph(l) | 21.25 | 33.75 | 27.63 | 2.30 |
| Ch(r)-T(r) | 81.68 | 118.86 | 103.22 | 7.21 |
| Ch(l)-T(l) | 81.28 | 119.70 | 102.68 | 7.40 |
| *Angular lip measurements* | | | | |
| UL inclin | 15.06 | 103.73 | 43.69 | 14.62 |
| LL inclin | 10.01 | 44.42 | 19.78 | 6.33 |
| Lab-ment ang | 95.20 | 158.59 | 127.37 | 12.20 |
| *Area/volume/ratio lip measurements* | | | | |
| Ls-Li/Ch-Ch | 13.01 | 45.13 | 30.32 | 6.94 |
| Ch(r)-ls-Ch(l)-sto | 77.85 | 313.17 | 195.52 | 46.70 |
| Ch(r)-li-Ch(l)-sto | 59.60 | 398.27 | 222.14 | 60.59 |
| Ch(r)-ls-Ch(l)-li | 190.87 | 667.39 | 417.66 | 87.91 |
| UL vol | 234.75 | 2517.00 | 1530.76 | 430.60 |
| LL vol | 521.55 | 4084.30 | 1740.44 | 536.05 |
| Tot lip volume | 1656.44 | 6377.22 | 3271.21 | 837.91 |

*Notes.* Measurement abbreviations and definitions detailed in Table 1. Age recorded in years. Linear lip measurements recorded in mm, angular lip measurements in degrees, lip area measurements in mm$^2$, and lip volume measurements in mm$^3$.

Pearson product—moment correlations were performed to investigate linear associations between lip morphology and age and BMI, in addition to correlations between the various labial measurements.

To assess intra-observer reliability, all measurements were repeated by the same investigator on 20 randomly selected images at least 14 days after the initial assessment. Another set of 20 randomly selected images were digitized by another investigator to check the inter-observer reliability. The repeated measures were evaluated using two-way, mixed-effects, intra-class correlations for absolute agreement on single measures. Data were processed using the Statistical Package for Social Sciences (SPSS®, version 23.0, IBM®) and Stata/SE™ 11.1. Statistical significance was set at 0.05.

## 3. Results

Reliability of repeated measurements within and between operators was high, with correlation coefficients ranging between 0.982 and 0.998 for intra-observer reliability, and between 0.978 and 0.996 for inter-observer reliability.

All linear, angular, area, and volume lip measurements displayed significant variability among the assessed Lebanese sample, as indicated by minimum values, maximum values, and standard deviations (Table 2). Among the linear measurements, the greatest

variability was displayed by the right and left labiotragal distances (69.45 ± 5.01 mm; range 57.08—84.96 and 64.73 ± 5.49 mm; range 51.99—82.70, respectively), followed by the upper and lower lip vermilion surface arcs (103.22 ± 7.21 mm; range 81.86—118.86 and 102.68 ± 7.40 mm; range 81.28—119.70, respectively). Among the angular lip measurements, lower lip inclination displayed the least variability (19.78 ± 6.33°; range 10.01—44.42). Upper and lower lip volumes exhibited significant variation, with values ranging between 234.75 and 2517.00 mm$^3$ for the upper lip and between 521.55 and 4084.30 mm$^3$ for the lower lip. On average, both lip area and volume were smaller in the upper than in the lower lip (195.52 ± 46.70 mm$^2$ compared with 222.14 ± 60.59 mm$^2$ and 1530.76 ± 430.60 mm$^3$ compared with 1740.44 ± 536.05 mm$^3$).

### 3.1. Sexual dimorphism

The majority of the assessed linear and angular lip morphology measurements displayed statistically significant gender differences ($p \leq 0.037$; Table 3), the only exceptions being the vermilion height of the upper lip ($p = 0.077$), left upper lip lateral height ($p = 0.053$), and lower lip inclination ($p = 0.708$). For 18 out of the 20 linear measurements with statistically significant differences between genders, the values were larger in males by a difference ranging

**Table 3**
Gender differences in lip morphology (n = 122).

| | Males (M) (n = 47) | Females (F) (n = 75) | Difference (M − F) | Student's t-test | |
|---|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SE) | Test statistic | p-value |
| *Linear lip measurements* | | | | | |
| Cph-Cph | 12.96 (1.71) | 10.87 (2.05) | 2.09 (0.35) | 5.934 | <0.001** |
| Chr-Chl | 52.35 (3.36) | 49.45 (3.19) | 2.90 (0.59) | 4.909 | <0.001** |
| Sn-Sto | 24.40 (2.5) | 22.06 (2.33) | 2.34 (0.43) | 5.397 | <0.001** |
| Sn-Ls | 18.15 (3.41) | 14.97 (2.63) | 3.18 (0.57) | 5.533 | <0.001** |
| Ls-Sto | 7.58 (1.82) | 8.10 (1.46) | −0.52 (0.29) | −1.784 | 0.077 |
| Li-Sl | 14.75 (2.9) | 11.60 (2.64) | 3.15 (0.5) | 6.337 | <0.001** |
| Sto-sl | 21.39 (2.52) | 18.99 (2.3) | 2.40 (0.43) | 5.551 | <0.001** |
| Sto-li | 8.16 (2.62) | 9.07 (1.72) | −0.90 (0.43) | −2.127 | 0.037* |
| Ls-Li | 14.17 (3.8) | 15.93 (2.77) | −1.77 (0.58) | −3.061 | 0.003** |
| Sn-Sl | 45.63 (3.81) | 40.85 (3.83) | 4.79 (0.7) | 6.882 | <0.001** |
| UL verm S arc | 72.12 (5.01) | 67.88 (4.48) | 4.24 (0.85) | 4.996 | <0.001** |
| LL verm S arc | 67.13 (6.05) | 63.33 (4.75) | 3.81 (1.02) | 3.130 | 0.002** |
| Ch(r)-Sto | 29.01 (2.54) | 27.63 (2.35) | 1.38 (0.44) | 5.376 | <0.001** |
| Ch(l)-Sto | 30.46 (2.42) | 28.22 (2.22) | 2.24 (0.42) | 8.527 | <0.001** |
| Sbal(r)-Ls | 24.15 (3.26) | 19.55 (2.35) | 4.60 (0.54) | 8.486 | <0.001** |
| Sbal(l)-Ls | 24.53 (3.23) | 19.94 (2.45) | 4.59 (0.54) | 8.415 | <0.001** |
| Sbal(r)-Cph(r) | 20.61 (3.07) | 16.45 (1.92) | 4.16 (0.49) | 8.463 | <0.001** |
| Sbal(l)-Cph(l) | 20.65 (2.95) | 16.62 (1.87) | 4.02 (0.48) | 1.950 | 0.053 |
| Ch(r)-Cph(r) | 28.01 (2.23) | 27.17 (2.44) | 0.84 (0.43) | 3.820 | <0.001** |
| Ch(l)-Cph(l) | 28.55 (2.38) | 27.02 (2.11) | 1.53 (0.4) | 10.090 | <0.001** |
| Ch(r)-T(r) | 109.26 (5.45) | 99.38 (5.35) | 9.88 (0.98) | 9.649 | <0.001** |
| Ch(l)-T(l) | 108.71 (5.75) | 98.85 (5.56) | 9.87 (1.02) | −4.017 | <0.001** |
| *Angular lip measurements* | | | | | |
| UL inclin | 37.32 (12.15) | 47.17 (14.15) | −9.84 (2.45) | −2.440 | 0.016* |
| LL inclin | 18.09 (4.84) | 20.80 (6.72) | −2.71 (1.11) | −0.375 | 0.708 |
| Lab-ment ang | 126.64 (10.72) | 127.47 (12.82) | −0.83 (2.2) | −4.627 | <0.001** |
| *Area/volume/ratio lip measurements* | | | | | |
| Ls-Li/Ch-Ch | 27.04 (6.97) | 32.34 (5.9) | −5.30 (1.15) | −0.300 | 0.765 |
| Ch(r)-ls-Ch(l)-sto | 194.52 (53.36) | 197.21 (40.86) | −2.69 (8.96) | −0.723 | 0.472 |
| Ch(r)-li-Ch(l)-sto | 216.62 (75.25) | 225.48 (50.15) | −8.86 (12.25) | −0.731 | 0.466 |
| Ch(r)-ls-Ch(l)-li | 411.14 (105.92) | 422.69 (74.5) | −11.54 (15.8) | 1.628 | 0.106 |
| UL vol | 1612.61 (418.69) | 1489.12 (416.64) | 123.49 (75.87) | 1.455 | 0.148 |
| LL vol | 1797.64 (647.38) | 1704.57 (449.75) | 93.07 (106.29) | 5.934 | <0.001** |
| Tot lip volume | 3410.25 (888.64) | 3193.7 (777.91) | 216.55 (148.84) | 4.909 | <0.001** |

*Notes.* Measurement abbreviations and definitions detailed in Table 1. Age recorded in years. Linear lip measurements recorded in mm, angular lip measurements in degrees, lip area measurements in mm$^2$, and lip volume measurements in mm$^3$.
*Statistically significant at $p < 0.05$.
**Statistically significant at $p < 0.01$.

between $0.84 \pm 0.43$ mm and $9.88 \pm 0.98$ mm ($p < 0.001$). The vermilion height of the lower lip and of both lips combined, on the other hand, was on average larger in females, with a difference of $0.9 \pm 0.43$ mm ($p = 0.037$) and $1.77 \pm 0.58$ mm ($p = 0.003$), respectively. Both upper lip inclination and labiomental angle were more pronounced in males, with mean differences of $9.84 \pm 2.45°$ ($p = 0.016$) and $0.83 \pm 2.2°$ ($p < 0.001$), respectively.

Unlike the linear and angular lip measurements, the ratio, area, and volume measurements mostly displayed no statistically significant gender dimorphism ($p > 0.106$). The only exceptions were lower lip and total lip volumes, which were larger in males by mean differences of $93.07 \pm 106.29$ mm$^3$ ($p < 0.001$) and $216.55 \pm 148.84$ mm$^3$ ($p < 0.001$), respectively.

### 3.2. Exploratory pilot data on associations with BMI

The majority of the assessed individuals (74.6%) were categorized as having a healthy BMI (18.5–24.9). Only eight individuals were underweight (BMI < 18.5) and 22 were overweight (BMI ≥ 25), which precluded the application of robust statistical analyses on the association between BMI and lip morphology. Nonetheless, preliminary exploratory analysis using non-parametric tests (*data not shown*) suggests the presence of a statistically significant general trend for increased linear lip measurements in overweight individuals, and a decreased inclination of

the upper lip. None of the area or volume lip measurements displayed any significant associations with BMI category, whereas the percent ratio of total lip vermilion height to width was statistically significantly smaller in overweight individuals. Exploratory correlations between BMI and lip area and volume measurements were almost negligible (<0.1 and non-significant), whereas correlations with linear lip measurements were moderate for 10 out of the 22 linear lip measurements (0.32–0.59) (*data not shown*).

### 3.3. Correlations between linear measurements and lip area and volume

Five linear lip measurements, in addition to the ratio between total lip vermilion height to width, were strongly correlated with measurements of lip area and volume ($r \geq 0.5$; $p < 0.001$; Table 4). Vermilion height for each of the upper and lower lips was strongly and significantly correlated with the respective lip area and volume, in addition to total lip area and volume ($r \geq 0.573$; $p < 0.001$). In addition, the total cutaneous height of both lips was strongly correlated with lower and total lip volumes, whereas the vermilion surface arc of the lower lip was strongly correlated only with lower lip volume. Finally, the ratio of total lip vermilion height to width was significantly and strongly correlated with upper, lower, and total lip areas, and to lower and total lip volumes ($r \geq 0.547$; $p < 0.001$).

**Table 4**
Linear correlations between linear lip measurements and area/volume measurements displaying strong associations (r ≥ 0.5) (n = 122).

| | Ch(r)-ls-Ch(l)-sto | Ch(r)-li-Ch(l)-sto | Ch(r)-ls-Ch(l)-li | UL vol | LL vol | Tot lip vol |
|---|---|---|---|---|---|---|
| ls-Sto | 0.765[**] | | 0.715[**] | 0.647[**] | | 0.573[**] |
| Sto-li | | 0.896[**] | 0.868[**] | | 0.844[**] | 0.763[**] |
| Ls-Li | 0.690[**] | 0.813[**] | 0.927[**] | 0.582[**] | 0.716[**] | 0.757[**] |
| Sn-Sl | | | | | 0.542[**] | 0.547[**] |
| ch-li-ch = Ch-L(l)-LL(l)-Li-LL(r)-L(r)-Ch | | | | | 0.551[**] | |
| Ls-Li/Ch-Ch | 0.592[**] | 0.683[**] | 0.785[**] | | 0.574[**] | 0.611[**] |

*Note.* Correlation coefficients are Pearson product–moment correlation coefficients (*r*).
[**]Statistically significant at *p* < 0.01.

## 4. Discussion

Studies assessing morphometric measurements of the lips remains scarce. Benchmark studies on North American Caucasians, using direct anthropometry, were performed by Farkas et al. and the data have since been used extensively as references for facial soft tissue norms (Farkas and Posnick, 1992; Farkas, 1994; Farkas, 1994b; Hajnis et al., 1994). However, a comprehensive analysis of short tandem repeat (STR) loci in a sample of unrelated Lebanese adults has highlighted the presence of statistically significant differences in 6 of the 17 assessed loci in comparison with a European Caucasian population (Chouery et al., 2010). The authors additionally report significant differences in selected loci between the Lebanese population and Egyptian, Iraqi, and Syrian samples. These data emphasize both the inapplicability of data from studies carried out on European Caucasians to the Lebanese population, and the inappropriateness of generalizing about populations of the Mediterranean basin until genomic mapping clarifies the similarities and differences between them.

While conventional direct anthropometry remains the gold standard for the in-vivo assessment of soft tissue norms, its applicability to research studies is limited by its tedious and time-consuming nature, its high sensitivity to level of operator training and experience, its proneness to error, and the lack of permanent records, which are essential for data quality control in research studies (Sforza and Ferrario, 2006). In line with contemporary technological advancements, more recent studies have replaced conventional anthropometry with digitized or computerized 3D anthropometry, which not only addresses the abovementioned drawbacks but also allows for the estimation of more complex soft tissue morphometric dimensions, such as surface area and volume (Sforza et al., 2016). In particular, stereophotogrammetric digital anthropometry is a non-contact procedure, which eliminates the distortion possibly caused by surface pressure from calipers, is independent of head posture and provides rapid, non-invasive, and accurate measurements of facial soft tissue (Weinberg et al., 2004; Ardehali et al., 2007; Sawyer et al., 2009; Wong et al., 2010). The method's validity compared with manual anthropometry, in addition to its precision and reliability, have been confirmed by previous research studies (Ghoddousi et al., 2007; de Menezes et al., 2010).

Among the most notable findings of our study was the general trend for gender dimorphism to affect linear and angular measurements rather than labial area and volume, with the exception of lower lip volume (and, as a consequence, total lip volume). The gender dimorphism displayed by several of the linear labial dimensions in our sample corroborates the findings reported in previous research, but confirms that larger linear values in males are not a universal finding, and do not apply to all linear labial measurements (Ferrario et al., 2009; Al-Khatib et al., 2012). Although the lack of gender dimorphism in upper lip vermilion height supports previous reports (Ferrario et al., 2009; Sawyer et al., 2009; Sforza et al., 2010), the significantly larger lower lip vermilion height in females described in our Lebanese sample is a distinct finding. This is perhaps reflective of the unique Levant, Iranian, and Eurasian ancestry of the present-day Lebanese population (Haber et al., 2017). The gender dimorphism displayed by the lips in our sample endorses previous findings of sex-related differences in mandibular angle morphology (Ayoub et al., 2009), mandibular canine width and intercanine distance (Ayoub et al., 2014), and various hard tissue cephalometric norms (Ayoub et al., 2008) between Lebanese males and females.

Ferrario et al. (2009) and Sforza et al. (2010) reported no gender differences for lower lip vermilion height in white Italians, whereas Sawyer et al. (2009) reported significantly larger values in males in the United Kingdom (UK). In line with our data on the Lebanese sample, Sawyer et al. (2009) reported that upper lip volume did not, on average, differ between males and females in the UK. However, the authors also reported the absence of gender differences for lower and total lip volumes, which is in contrast with the results of our study. Ferrario et al. (2009) and Sforza et al. (2010), on the other hand, reported significantly larger volumes for both upper and lower lip in Italian males compared with females.

When compared with recent digital anthropometric data on other previously assessed populations, many of the linear Lebanese norms described in our research were similar (within 2 mm) to the norms described for Italian (Ferrario et al., 2000, 2009; Sforza et al., 2010) and UK white populations (Sawyer et al., 2009). However, total and cutaneous upper lip height, in addition to the total cutaneous height of both lips combined, were considerably larger in our Lebanese sample. Many measurements were also similar to those described for the Malay population (Al-Khatib et al., 2012), with notable exceptions: the cutaneous height of the upper lip was larger in the Lebanese sample, while the vermilion height of the upper lip and the cutaneous height of the lower lip were smaller; right and left lateral lip heights and right and left upper lip lateral heights were larger in Lebanese males compared with Malay males, but similar between females of the two populations. Although none of these studies assessed the angular positions of the lips, compared with the direct anthropometric values reported by Farkas (1994a) for Caucasians, Lebanese males and females possess considerably more proclined upper lips, more retroclined lower lips, and a deeper labiomental sulcus.

Although linear morphometric measurements are relatively resistant to methodological differences in data collection, area and volume measurements are highly technique sensitive, show considerable variations across studies, and must be compared with caution. Lip surface areas in Lebanese adults were similar to those described for northern Italians (Sforza et al., 2010) but smaller than described in the UK (Sawyer et al., 2009), whereas lip volumes were much smaller in our sample than described for either the Italians or the British. Our results nonetheless support previous research illustrating larger vermilion areas in the lower than in the upper lip (Ferrario et al., 2009; Sforza et al., 2010) although such a difference

was not found by Sawyer et al. (2009). Published data on the difference in volume between upper and lower lips contrast with our results, with larger upper than lower lip volumes reported for the Italian and UK samples (Sawyer et al., 2009; Sforza et al., 2010). The only regional study assessing anthropometric lip measurements has been carried out by Sforza et al. (2016) on the Sudanese population, but with considerable differences in methodology and measurements assessed, comparison is very limited. It is noteworthy, however, that our Lebanese sample displayed smaller norms for the labiomental angle, and thereby a deeper average sulcus, than the Sudanese norm.

Few studies have investigated the correlations between the various labial dimensions and, to our knowledge, none has reported the correlations between linear and area/volume labial measurements. Al-Khatib et al. (2012) noted significant correlations between horizontal labial dimensions but weak ones between the vertical and horizontal measurements. Notably, our data illustrate strong and statistically significant correlations between the vermilion height of each of the lips with the respective lip area and volume, a finding that, to our knowledge, has not been confirmed in previous literature.

The presence of an association between larger patient BMI and increased linear lip measurements, but a lack of influence of BMI on area and volumetric labial dimensions, is a novel finding that has not previously been reported. This perhaps suggests that the effects of increased BMI are linked to targeted stretching of the soft-tissue lips and consequent alterations in specific linear dimensions, but not to structural differences in lip areas and volumes. These effects appear to be similar to those noted in aging lips, whereby it has been shown that aging does not result in a decrease in labial volume, but rather a redistribution of labial dimensions, which manifest as a reduction in vermilion height and increased mouth width (Sforza et al., 2010). Nonetheless, the exploratory nature of our data and the small sample sizes for underweight and overweight individuals necessitate the validation of our findings by future studies before generalization.

Additional research considerations include the need to standardize methodology for patient positioning while taking labial measurements (lips relaxed, closed, open, or displaying varying degrees of contraction), because these variations have been shown to cause significant variability in resulting linear, area, and volume measurements (Johnston et al., 2003; Sawyer et al., 2009). Recent technological refinements in stereophotogrammetric technology have made it more accessible and should encourage further similar research on various populations, utilizing consistently comparable data acquisition methodology in order to allow meaningful contrasts between assessed populations. With respect to Middle-Eastern populations, future research may aim for sufficient representation of a wide range of age groups and BMI in order to adequately assess the effects of both factors.

## 5. Conclusion

This study generated the first database for the quantitative 3D description of labial anthropometric features in the Lebanese population. Linear and angular lip measurements exhibited gender dimorphism, whereas lip area and volume measurements were generally similar across both sexes. Five linear lip measurements (upper and lower lip vermilion heights; total cutaneous height of upper and lower lips; vermilion surface arc of lower lip), in addition to the ratio between total lip vermilion height to width, were strongly correlated with measurements of lip area and volume. Preliminary exploratory data highlighted the presence of larger labial linear measurements in overweight individuals, but no effects on labial area or volume. The values provided by this study should prove useful as population-specific norms in treatment planning for patients with Lebanese ancestry attending orthodontic, maxillofacial, or plastic surgery clinics. Future research to include a sample over a wider age range is recommended.

## Conflict of interest disclosure

The authors declare that they have no conflict of interest in this research study.

## Acknowledgment

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2018.12.001.

## References

Aeria G, Claes P, Vandermeulen D, Clement JG: Targeting specific facial variation for different identification tasks. Forensic Sci Int 201: 118–124, 2010

Al-Khatib AR, Rajion ZA, Masudi SM, Hassan R, Anderson PJ, Townsend GC: Stereophotogrammetric analysis of nasolabial morphology among Asian Malays: influence of age and sex. Cleft Palate Craniofac J 49(4): 463–471, 2012

Arca S, Campadelli P, Lanzarotti R, Lipori G, Cervelli F, Mattei A: Improving automatic face recognition with user interaction. J Forensic Sci 57: 765–771, 2012

Ardehali B, Nourael SAR, Van Dam H, Dex E, Wood S, Nduka C: Objective assessment of keloid scars with three-dimensional imaging: quantifying response to intralesional steroid therapy. Plast Reconstr Surg 119(2): 556–561, 2007

Ayoub F, Rizk A, Yehya M, Cassia A, Chartouni S, Atiyeh F, et al: Sexual dimorphism of mandibular angle in a Lebanese sample. J Forensic Leg Med 16(3): 121–124, 2009

Ayoub F, Yehia M, Rizk A, Al-Tannir M, Abi-Farah A, Hamadeh G: Forensic norms of female and male Lebanese adults. J Forensic Odontostomatol 26(1): 18–23, 2008

Ayoub F, Shamseddine L, Rifai M, Cassia A, Diab R, Zaarour I, et al: Mandibular canine dimorphism in establishing sex identity in the Lebanese population. Int J Dent 4. https://doi.org/10.1155/2014/235204, 2014

Cattaneo C, Ritz-Timme S, Gabriel P, Gibelli D, Giudici E, Poppa P, et al: The difficult issue of age assessment on pedo-pornographic material. Forensic Sci Int 183: e21–e24, 2009

Claes P, Vandermeulen D, De Greef S, Willems G, Clement JG, Suetens P: Computerized craniofacial reconstruction: conceptual framework and review. Forensic Sci Int 201(1–3): 138–145, 2010

Chouery E, Coble MD, Strouss KM, Saunier JL, Jalkh N, Medlej-Hashim M, et al: Population genetic data for 17 STR markers from Lebanon. Leg Med 12(6): 324–326, 2010

De Greef S, Claes P, Vandermeulen D, Mollemans W, Suetens P, Willems G: Large-scale in-vivo Caucasian facial soft tissue thickness database for craniofacial reconstruction. Forensic Sci Int 159(Suppl. 1): S126–S146, 2006

de Menezes M, Rosati R, Ferrario VF, Sforza C: Accuracy and reproducibility of a 3-dimensional stereophotogrammetric imaging system. J Oral Maxillofac Surg 68(9): 2129–2135, 2010

Dong Y, Zhao Y, Bai S, Wu G, Wang B: Three-dimensional anthropometric analysis of the Chinese nose. J Plast Reconstr Aesthet Surg 63(11): 1832–1839, 2010

Fang F, Clapham PJ, Chung KC: A systematic review of interethnic variability in facial dimensions. Plast Reconstr Surg 127: 874–881, 2011

Farkas LG: Anthropometry of the head and face. New York: Raven Press, 1994

Farkas LG: Anthropometry of the attractive North American caucasian face. In: Farkas LG (ed.), Anthropometry of the head and face, 2nd ed. New York: Raven Press, 159–179, 1994a

Farkas LG: Examination. In: Farkas LG (ed.), Anthropometry of the head and face, 2nd ed. New York: Raven Press, 3–56, 1994b

Farkas LG, Posnick JC: Growth and development of regional units in the head and face based on anthropometric measurements. Cleft Palate Craniofac J 29(4): 301–302, 1992

Fernández-Riveiro P, Smyth-Chamosa E, Suárez-Quintanilla D, Suárez-Cunqueiro M: Angular photogrammetric analysis of the soft tissue facial profile. Eur J Orthod 25(4): 393–399, 2003

Ferrario VF, Rosati R, Peretta R, Dellavia C, Sforza C: Labial morphology: a 3-dimensional anthropometric study. J Oral Maxillofac Surg 67(9): 1832–1839, 2009

Ferrario VF, Sforza C, Poggio CE, Schmitz JH: Soft-tissue facial morphometry from 6 years to adulthood: a three-dimensional growth study using a new modeling. Plast Reconstr Surg 103(3): 768–778, 1999

Ferrario VF, Sforza C, Serrao G: A three-dimensional quantitative analysis of lips in normal young adults. Cleft Palate Craniofac J 37(1): 48—54, 2000

Ferrario VF, Sforza C: Size and shape of soft tissue facial profile: effects of age, gender, and skeletal class. Cleft Palate Craniofac J 34: 498—504, 1997

Ghoddousi H, Edler R, Haers P, Wertheim D, Greenhill D: Comparison of three methods of facial measurement. Int J Oral Maxillofac Surg 36(3): 250—258, 2007

Haber M, Doumet-Serhal C, Scheib C, Xue Y, Danecek P, Mezzavilla M, et al: Continuity and admixture in the last five millennia of Levantine history from ancient Canaanite and present-day Lebanese genome sequences. Am J Hum Genet 101(2): 274—282, 2017

Hajnis K, Farkas LG, Ngim RCK, Lee ST, Venkatadri G: Racial and ethnic morphometric differences in the craniofacial complex. In: Farkas LG (ed.), Anthropometry of the head and face, 2nd ed. New York: Raven Press, 201—218, 1994

Hennessy RJ, McLearie S, Kinsella A, Waddington JL: Facial surface analysis by 3D laser scanning and geometric morphometrics in relation to sexual dimorphism in cerebral—craniofacial morphogenesis and cognitive function. J Anat 207(3): 283—295. https://doi.org/10.1111/j.1469-7580.2005.00444.x, 2005

Hwang HS, Kim K, Moon DN, Kim JH, Wilkinson C: Reproducibility of facial soft tissue thicknesses for craniofacial reconstruction using cone-beam CT images. J Forensic Sci 57: 443—448, 2012

Jayaratne YS, Deutsch CK, Zwahlen RA: Nasal morphology of the Chinese: three-dimensional reference values for rhinoplasty. Otolaryngol Head Neck Surg 150(6): 956—961, 2014

Johnston DJ, Millett DT, Ayoub AF, Bock M: Are facial expressions reproducible? Cleft Palate Craniofac J 40(3): 291—296, 2003

Kochel J, Meyer-Marcotty P, Strnad F, Kochel M, Stellzig-Eisenhauer A: 3D soft tissue analysis — part 1: sagittal parameters. Orofac Orthop 71(1): 40—52, 2010

Lee Y, Chun YS, Kang N, Kim M: Volumetric changes in the upper airway after bimaxillary surgery for skeletal class III malocclusions: a case series study using 3-dimensional cone-beam computed tomography. J Oral Maxillofac Surg 70(12): 2867—2875, 2012

Li K-Z, Guo S, Sun Q, Jin S-F, Zhang X, Xiao M, et al: Anthropometric nasal analysis of Han Chinese young adults. J Craniomaxillofac Surg 42(2): 153—158, 2014

Lundström A, Forsberg C-M, Peck S, McWilliam J: A proportional analysis of the soft tissue facial profile in young adults with normal occlusion. Angle Orthod 52: 127—133, 1992

Mack MR: Vertical dimension: a dynamic concept based on facial form and oropharyngeal function. J Prosthet Dent 66: 478—485, 1991

Möller M, Schaupp E, Massumi-Möller N, Zeyher C, Godt A, Berneburg M: Reference values for three-dimensional surface cephalometry in children aged 3—6 years. Orthod Craniofac Res 15(2): 103—116, 2012

Mutsvangwa TE, Meintjes EM, Viljoen DL, Douglas TS: Morphometric analysis and classification of the facial phenotype associated with fetal alcohol syndrome in 5- and 12-year-old children. Am J Med Genet A 152A: 32—41, 2010

Mutsvangwa TE, Veeraragoo M, Douglas TS: Precision assessment of stereo-photogrammetrically derived facial landmarks in infants. Ann Anat 193: 100—105, 2011

Ritz-Timme S, Gabriel P, Tutkuviene J, Poppa P, Obertova Z, Gibelli D, et al: Metric and morphological assessment of facial features: a study on three European populations. Forensic Sci Int 207(239): e1—e8, 2011

Sawyer AR, See M, Nduka C: 3D stereophotogrammetry quantitative lip analysis. Aesthet Plast Surg 33(4): 497—504, 2009

Sforza C, De Menezes M, Ferrario V: Soft- and hard-tissue facial anthropometry in three dimensions: what's new. J Anthropol Sci 91: 159—184, 2013

Sforza C, Dolci C, Gibelli DM, Codari M, Pucciarelli V, Ferrario VF, et al: Age-related and sex-related changes in the normal soft tissue profile of native northern Sudanese subjects: a cross-sectional study. Br J Oral Maxillofac Surg 54(2): 192—197, 2016

Sforza C, Ferrario VF: Three-dimensional analysis of facial morphology: growth, development and aging of the orolabial region. Ital J Anat Embryol 115(1—2): 141—145, 2010

Sforza C, Ferrario VF: Soft-tissue facial anthropometry in three dimensions: from anatomical landmarks to digital morphology in research, clinics and forensic anthropology. J Anthropol Sci 84: 97—124, 2006

Sforza C, Grandi G, Binelli M, Dolci C, De Menezes M, Ferrario VF: Age- and sex-related changes in three-dimensional lip morphology. Forensic Sci Int 200(1—3), 2010 182.e1—7

Sforza C, Grandi G, De Menezes M, Tartaglia GM, Ferrario VF: Age- and sex-related changes in the normal human external nose. Forensic Sci Int 204(1—3), 2011 205. e1—9

Skinazi GL, Lindauer SJ, Isaacson RJ: Chin, nose, and lips: normal ratios in young men and women. Am J Orthod Dentofacial Orthop 106: 518—523, 1994

Smeets D, Claes P, Vandermeulen D, Clement JG: Objective 3D face recognition: evolution, approaches and challenges. Forensic Sci Int 201: 125—132, 2010

Tollefson TT, Sykes JM: Computer imaging software for profile photograph analysis. Arch Facial Plast Surg 9(2): 113—119, 2007

Vahdettin L, Altuğ Z: Longitudinal soft-tissue profile changes in adolescent Class I subjects. J Orofac Orthop 73(6): 440—453, 2012

Verze L, Nasi A, Quaranta F, Vasino V, Prini V, Ramieri G: Quantification of facial movements by surface laser scanning. J Craniofac Surg 22(60—65), 2011

Weinberg SM, Scott NM, Neiswanger K, Brandon CA, Marazita ML: Digital three-dimensional photogrammetry: evaluation of anthropometric precision and accuracy using a Genex 3D camera system. Cleft Palate Craniofac J 41(5): 507—518, 2004

Wilkinson C: Facial reconstruction — anatomical art or artistic anatomy? J Anat 216(2): 235—250, 2010

Wong WW, Davis DG, Camp MC, Gupta SC: Contribution of lip proportions to facial aesthetics in different ethnicities: a three-dimensional analysis. J Plast Reconstr Aesthet Surg 63(12): 2032—2039, 2010