

ORIGINAL RESEARCH



Cephalometric Evaluation of the Hyoid Bone Position in Lebanese Healthy Young Adults

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ABSTRACT

Introduction: The objectives of this study are to assess hyoid sagittal and vertical position, and potential correlations with gender, skeletal class, and anthropometrics.

Materials and methods: Twenty-seven cephalometric linear, angular, and ratio measurements for the hyoid were recorded on lateral cephalograms obtained from 117 healthy young Lebanese adults. Anthropometric parameters including height, weight, body mass index (BMI), and neck circumference (NC) were measured.

Results: Statistically significant gender differences were demonstrated for 21 out of 27 parameters considered. All linear and two out of three angular measurements defining the vertical hyoid position were larger in males compared with females. Five linear, one angular, and two ratio measurements showed differences in the sagittal dimension. Skeletal classes did not influence the sagittal and vertical hyoid position. Anthropometric variables as height were strongly correlated to the vertical hyoid position, while weight correlated more sagittally.

Conclusion: Cephalometric norms for hyoid position were established, sexual dimorphism and ethnic differences were demonstrated. Skeletal patterns did not influence the sagittal and vertical hyoid bone position. Anthropometric parameters, such as BMI correlated the least to both vertical and sagittal hyoid position measurements, while the impact of height and weight as separate entities made a paradigm shift providing accurate and strong correlation of the vertical hyoid position to the height, and the sagittal hyoid position to the weight of individuals.

Clinical significance: The cephalometric norms for the hyoid bone position in the Lebanese population established in the present study are of paramount clinical importance and should be considered in planning combined orthodontic and breathing disorders treatments.

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INTRODUCTION

The hyoid bone position is turning into a stepping stone in airway assessment and in managing all kinds of orthodontic treatment, especially those related to sleep disordered breathing and obstructive sleep apnea. The horseshoe-shaped hyoid is the unique bone structure of the body that has no bony articulations and is located between the mandibular symphysis anteriorly and the larynx posteriorly.^{1,2} It is connected to the pharynx, tongue, mandible, sternum, the scapula, thyroid cartilage, and cranium of the facial skeleton through the infra and suprahyoid muscles. The hyoid bone plays an important role in maintaining airway patency and the upright postural position of the head,³ as well as preventing regurgitation.^{4,5}

The hyoid bone position is influenced by the head posture inclination and mandible rotation.⁶⁻¹¹ Hyoid movement is biomechanically linked to head posture and body position during various oral functions in close association with tongue activity.¹² A study on dental classes showed that the tongue root of patients with Angle class II malocclusion was farther backward than were those of Angle class III malocclusion.¹³ The influence of the sagittal skeletal class on the hyoid bone position was studied in relation to the ANB angle.^{8,14-19} Different studies concluded that the hyoid-cervical vertebra relationship is more reliable than the relationship of the hyoid to the skull and mandible.²⁰⁻²² Among mouth breathers and tongue-thrusters, hyoid position was not permanently affected to

a point it could be used as a reference landmark in cephalometric analysis for orthodontic treatment purposes.²⁰ The inferior-posterior displacement of hyoid bone is most likely due to the enlargement of tongue volume.²³ In an age-related study, the horizontal position of the hyoid bone was shown to be stable.²⁴ In a therapeutic perspective, it was shown that the hyoid bone position became closer to the mandibular plane (MP), when obstructive sleep apnea patients were asked to protrude their mandible in the most comfortable position.²⁵ Evidence of pharyngeal lengthening and a more caudally located hyoid bone²⁶ occurs with age.²⁷ To avoid upper airways collapse, the hyoid bone renders a kinematic protective position.²⁸ When mandibles moved posteriorly, the hyoid bone and tongue, which are primary structures, did not follow in order to ensure the stability and patency of the pharyngeal airways.²⁸ On the contrary, other studies have shown that the hyoid bone followed the advancement or setback movement in orthognathic surgery cases.²⁹⁻³²

OBJECTIVES

The objectives of the present cross-sectional study were to cephalometrically assess lateral cephalograms, in healthy young adult Lebanese subjects, the hyoid bone position in different genders and sagittal skeletal patterns, in order to establish cephalometric norms or references for a Lebanese population. This study is of paramount interest for orthodontists and other dental or medical head and neck-related specialists. Therefore, a secondary objective is to correlate the hyoid variables with the anthropometric data of the studied sample.

MATERIALS AND METHODS

Subject Selection

One hundred seventeen healthy young adult participants were recruited from the graduate students at the Lebanese University, Faculty of Dental Medicine. Selection was done according to the following inclusion criteria: Age range between 21 and 25 years, presence of a complete dentition, and Lebanese in origin. Exclusion criteria include healthy subjects with no morphological anomalies, no previous orthodontic treatment or surgeries, and no pathophysiology of the upper airways that affect the neck and craniofacial structures. The procedures were explained thoroughly, and an informed consent was obtained. The study was approved by the Ethical Committee of the Lebanese University.

Cephalometric Analysis

Digital lateral cephalograms were carried out in a standardized manner in the Department of Radiology, using

the Kodak 8000/C apparatus with a charge-coupled device digital sensor (Carestream Dental, Toronto, Canada). Subjects were positioned in the cephalometer in a natural head position. To avoid the impact of posture and function (i.e., breathing and swallowing), individuals were asked to keep their teeth in maximum intercuspation according to the standardized conditions described by Siersbæk-Nielsen and Solow³³ and to keep their tongue in a relaxed position according to the protocol of Daraze et al³⁴ for upper airway cephalometric assessment.

The digital cephalograms were analyzed using the Viewbox cephalometric tracing software (Viewbox Version 4.0.1.6, 2012, dHAL Software, Kifissia, Greece). Cephalometric landmarks and planes used for hyoid position measurements are represented in Table 1.

The hyoid bone position was identified by sets of lines, angles, and ratios, using 27 variables divided as follows (Fig. 1):

- Vertical hyoid position represented by:
 - Linear measurements: H-SN, H-S, H-PP, H-PNS, H-MP, H-FH, H-Cv3iaRgn, H-BaN, H-Tg Dorsum, H-Cv3ia Vertical;
 - Angular measurements: H-Go/H-Me, H-Me-Go, H-Gn-Go.
- Sagittal hyoid position represented by:
 - Linear measurements: H-RGn, H-Me, H-Gn, H-B, H-N (FH), H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW;
 - Angular measurement: H-S-N;
 - Ratios: H-MP/Cv3ia-Me, H-Me/Cv3ia-Me, H-Cv3ia/Cv3ia-Me.

Linear and angular measurements were expressed in millimeters and degrees respectively, with the two-decimal format.

Landmark identification and cephalometric tracing were completed after calibration exercises for two clinicians. Subsequently, intra- and interobserver agreement was assessed using one-way intraclass correlation coefficient (ICC) and 95% confidence interval (CI). High intraobserver reliability with the ICC values of 0.998 and 0.999 were obtained for linear and angular measurements respectively. The ICC values for interobserver reliability were 0.997 and 1.000 with 95% CI (-1.05, 0.50) and (0.17, 1.01) for linear and angular measurements respectively.

The subjects were classified into three skeletal sagittal types according to their ANB angles as class I ($1^\circ \leq \text{ANB} \leq 3^\circ$), class II ($\text{ANB} > 3^\circ$), and class III ($\text{ANB} < 1^\circ$).³⁵

Anthropometric measurements were performed. Height and NC were measured to the nearest 0.01 m. Body weight was determined to the nearest 0.05 kg. The BMI in kg/m^2 was calculated as weight (kg) divided by the height-squared (m^2).

Table 1: Cephalometric landmarks and planes used for hyoid position measurements

Landmarks and reference planes	Definition
ANS	Anterior nasal spine
B	Point B, most posterior point of the bony curvature on the mandible below infradentale and above pogonion
Ba	Basion, lowest point on the anterior rim of the foramen magnum
Cv3ia	Most anteroinferior point of the third cervical vertebra
Cv4ia	Most anteroinferior point of the fourth cervical vertebra
Eb	Epiglottis base
FH	Frankfort horizontal plane (Po-Or)
Gn	Gnathion, lowest and most anterior point of the chin (the half-divided angle of Na-Pg plane and Go-Me plane)
Go	Gonion, point of the bony contour of the gonial angle located by bisecting the posterior and inferior tangents to the borders of the mandible
H	Hyoidale, most anterior and superior point of the hyoid bone
Me	Menton, most inferior point on the bony chin
MP	Mandibular plane through gonion and menton
N	Nasion, most anterior point on the frontal suture in the mid sagittal plane
Or	Orbitale, lowest point on the inferior rim of the orbit
PNS	Posterior nasal spine
Po	Porion, the midpoint of the upper contour of the external auditory canal (anatomic porion) or a point midway between the top of the image of the left and right ear-rods of the cephalostat (machine porion)
PP	Palatal plane (ANS-PNS)
RGn	Retrognathion, the posterior-lower point of the mandibular symphysis
S	Sella, midpoint of the hypophyseal fossa
Tg Dorsum	Tongue dorsum, most superior point of the superior surface of the tongue

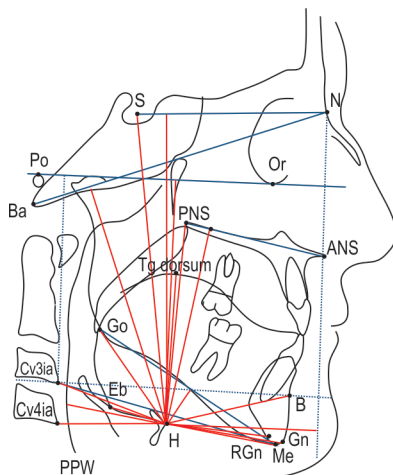


Fig. 1: H-SN (distance between H and SN); H-S (distance between H and S); H-PP (distance between H and PP [ANS-PNS]); H-PNS (distance between H and PNS); H-MP (distance between H and MP [Go-Me]); H-FH (distance between H and FH); H-Cv3iaRgn (distance between H and Cv3ia-RGn); H-BaN (distance between H and the projection of H on Ba-N); H-Tg Dorsum (distance between H and Tg Dorsum [most superior point on tongue dorsum]); H-Cv3ia Vertical (distance between H and Hd [projection of H on the line connecting Cv3ia-Cv3ia' parallel to FH]); H-Go/H-Me (angle between H-Go and H-Me); H-Me-Go (angle formed by the two lines H-Me and Me-Go); H-Gn-Go (angle formed by the two lines H-Gn and Gn-Go); H-RGn (distance between H and RGn); H-Me (distance between H and Me); H-Gn (distance between H and Gn); H-B (distance between H and point B of the symphysis); H-N (FH) (distance between H and N perpendicular to FH); H-Cv3ia Horizontal (distance between H and Cv3ia [projection of H on a line passing by Cv3ia and Cv3ia' perp to FH]); H-Cv3ia (distance between H and Cv3ia); H-Cv4ia (distance between H and Cv4ia); H-Eb (distance between H and Eb); H-PPW (distance between H and the posterior pharyngeal wall); H-S-N (angle by HS and SN); H-Cv3ia/Cv3ia-Me (ratio of the two distances H-Cv3ia and Cv3ia-Me); H-Me/Cv3ia-Me (ratio of the two distances H-Me and Cv3ia-Me); H-MP/Cv3ia-Me (ratio of the two distances H-MP and Cv3ia-Me)

Statistical Analysis

Descriptive statistics were performed for all cephalometric and anthropometric variables used in this study. After confirmation of the normal sample distribution, paired t-test, analysis of variance, and Pearson correlation were applied to evaluate the impact of modifying variables (gender, skeletal class, weight, height, and BMI) on the hyoid bone position. $p < 0.05$ was set for statistical significance.

The sample size of 117 participants was justified to estimate any of the cephalometric and anthropometric variables to be within a margin error of at most 0.2 standard deviation (SD), using 95% CI that could be obtained with just a 100 sample size. This moderate to large (0.6 SD and above) sample size allowed us to detect differences, if any, between parameters, such as gender and classes.

RESULTS

Descriptive statistics and comparisons are reported in Tables 2 to 4.

When hyoid position variables were compared between males and females (Table 2), statistically significant differences were demonstrated for 21 out of 27 parameters considered. All linear measurements (H-SN, H-S, H-PP, H-PNS, H-MP, H-FH, H-Cv3iaRgn, H-BaN, H-Tg Dorsum, H-Cv3ia Vertical) and two out of three angular measurements (H-Me-Go, H-Gn-Go) defining the vertical hyoid position were significantly larger in males compared with females. Statistically significant differences were found in 8 out of 13 variables defining

Table 2: Descriptive analysis of the selected cephalometric hyoid variables in the sample population and comparison between genders

Hyoid variables	Males (n = 48)	Females (n = 69)	p-value	Overall (n = 117)
	Mean ± SD	Mean ± SD		Mean ± SD
<i>Vertical</i>				
<i>Linear measurements</i>				
H-SN	126.12 ± 9.47	106.29 ± 7.48	<0.001*	114.43 ± 12.84
H-S	126.63 ± 9.42	106.76 ± 7.42	<0.001*	114.84 ± 12.81
H-PP	75.57 ± 6.37	61.94 ± 5.96	<0.001*	67.49 ± 9.08
H-PNS	76.00 ± 6.30	63.19 ± 5.87	<0.001*	68.40 ± 8.73
H-MP	18.37 ± 6.52	14.09 ± 5.26	<0.001*	15.83 ± 6.15
H-FH	101.17 ± 8.14	84.87 ± 7.32	<0.001*	91.50 ± 11.09
H-Cv3iaRgn	5.78 ± 5.92	-0.16 ± 5.24	<0.001*	2.26 ± 6.24
H-BaN	94.18 ± 8.61	77.45 ± 7.34	<0.001*	84.31 ± 11.40
H-Tg Dorsum	67.98 ± 8.33	58.56 ± 6.24	<0.001*	62.33 ± 8.49
H-Cv3ia Vertical	-10.82 ± 5.71	-3.80 ± 6.48	<0.001*	-6.68 ± 7.07
<i>Angular measurements</i>				
H-Go/H-Me	131.16 ± 16.42	136.34 ± 14.32	0.071	134.23 ± 15.36
H-Me-Go	22.90 ± 9.35	16.73 ± 6.56	<0.001*	19.24 ± 8.36
H-Gn-Go	22.23 ± 8.33	16.43 ± 6.11	<0.001*	18.79 ± 7.62
<i>Sagittal</i>				
<i>Linear measurements</i>				
H-RGn	43.81 ± 5.38	44.17 ± 5.53	0.722	44.02 ± 5.45
H-Me	48.43 ± 5.75	49.64 ± 5.72	0.265	49.15 ± 5.74
H-Gn	52.70 ± 5.51	53.93 ± 6.03	0.265	53.43 ± 5.83
H-B	59.14 ± 5.10	57.15 ± 5.72	0.054	57.96 ± 5.54
H-N (FH)	65.43 ± 9.41	64.90 ± 9.25	0.766	65.11 ± 9.28
H-Cv3ia Horizontal	41.39 ± 4.83	35.79 ± 4.09	<0.001*	38.07 ± 5.18
H-Cv3ia	43.13 ± 4.98	36.57 ± 3.92	<0.001*	39.24 ± 5.43
H-Cv4ia	47.98 ± 5.03	44.13 ± 5.32	<0.001*	45.70 ± 5.52
H-Eb	17.43 ± 3.75	13.89 ± 2.48	<0.001*	15.33 ± 3.51
H-PPW	38.02 ± 4.64	31.45 ± 3.30	<0.001*	34.14 ± 5.06
<i>Angular measurements</i>				
H-S-N	88.24 ± 4.93	92.62 ± 4.59	<0.001*	90.82 ± 5.19
<i>Ratios</i>				
H-MP/Cv3ia-Me	0.21 ± 0.08	0.17 ± 0.06	0.003*	0.18 ± 0.07
H-Me/Cv3ia-Me	0.54 ± 0.04	0.58 ± 0.03	<0.001*	0.56 ± 0.04
H-Cv3ia/Cv3ia-Me	0.48 ± 0.04	0.43 ± 0.04	<0.001*	0.45 ± 0.5

*Statistically significant differences between genders

the sagittal hyoid position. Five linear measurements (H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW), all angular (H-S-N) and ratio measurements (H-MP/Cv3ia-Me, H-Me/Cv3ia-Me, H-Cv3ia/Cv3ia-Me) showed statistically significant differences between males and females.

Comparison between skeletal classes I, II, and III showed statistically significant differences in 8 out of 27 variables (Table 3). The only significant difference for vertical measurements was demonstrated between classes II and III individuals relative to H-BaN, showing greater values in class III subjects. For the hyoid sagittal position, more statistical significance was demonstrated between classes II and III for five linear measurements (H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW), one angular (H-S-N), and one ratio (H-Cv3ia/Cv3ia-Me).

Between classes I and II, two variables were statistically significant (H-Eb, H-S-N), while H-PPW was found to be statistically significant between classes I and III.

Correlation between anthropometric and hyoid variables is shown in Table 4. A significant positive correlation was found between BMI, linear, and ratio measurements; 7 vertical (H-SN, H-S, H-PP, H-PNS, H-FH, H-BaN, H-Tg Dorsum), 6 sagittal (H-B, H-Cv3ia horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW), and 1 ratio (H-Cv3ia/Cv3ia-Me), while NC showed 2 vertical linear (H-MP, H-Cv3iaRgn) and 2 angular (H-Me-Go, H-Gn-Go) additional correlations. A significant negative correlation was found in both BMI and NC with H-Me/Cv3ia-Me ratio measurement. Neck circumference showed 1 linear vertical (H-Cv3ia Vertical) and 1 angular sagittal (H-Me/Cv3ia-Me) additional correlations. H-Cv3ia vertical, H-S-N, and H-Me/

Table 3: Descriptive analysis of the selected cephalometric hyoid variables in each of the three skeletal groups without gender differences

Variables	Class I (M = 13; F = 17)		Class II (M = 20; F = 47)		Class III (M = 15; F = 5)		p-value	Class I (M = 13; F = 17)		Class III (M = 15; F = 5)		p-value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD			
Vertical												
<i>Linear measurements</i>												
H-SN	115.31 ± 11.19	112.66 ± 12.99	NS	112.66 ± 12.99	119.03 ± 13.99	NS	115.31 ± 11.19	119.03 ± 13.99	NS	119.03 ± 13.99	NS	
H-S	115.69 ± 11.44	113.14 ± 12.89	NS	113.14 ± 12.89	119.58 ± 14.00	NS	115.69 ± 11.44	119.58 ± 14.00	NS	119.58 ± 14.00	NS	
H-PP	67.24 ± 8.52	66.70 ± 8.88	NS	66.70 ± 8.88	70.85 ± 10.28	NS	67.24 ± 8.52	70.85 ± 10.28	NS	70.85 ± 10.28	NS	
H-PNS	67.95 ± 8.19	67.78 ± 8.49	NS	67.78 ± 8.49	71.61 ± 10.03	NS	67.95 ± 8.19	71.61 ± 10.03	NS	71.61 ± 10.03	NS	
H-MP	15.35 ± 6.94	15.89 ± 5.53	NS	15.89 ± 5.53	16.44 ± 7.26	NS	15.35 ± 6.94	16.44 ± 7.26	NS	16.44 ± 7.26	NS	
H-FH	92.363 ± 10.31	90.1 ± 10.80	NS	90.1 ± 10.80	95.08 ± 12.90	NS	92.363 ± 10.31	95.08 ± 12.90	NS	95.08 ± 12.90	NS	
H-Cv3iaRgn	2.74 ± 6.78	1.87 ± 5.71	NS	1.87 ± 5.71	2.98 ± 7.36	NS	2.74 ± 6.78	2.98 ± 7.36	NS	2.98 ± 7.36	NS	
H-BaN	87.27 ± 10.40	81.53 ± 10.53	NS	81.53 ± 10.53	89.19 ± 13.32	0.007*	87.27 ± 10.40	89.19 ± 13.32	NS	89.19 ± 13.32	NS	
H-Tg Dorsum	60.67 ± 7.07	62.69 ± 5.59	NS	62.69 ± 5.59	63.59 ± 10.07	NS	60.67 ± 7.07	62.69 ± 5.59	NS	62.69 ± 5.59	NS	
H-Cv3ia Vertical	-7.29 ± 7.44	-5.97 ± 6.57	NS	-5.97 ± 6.57	-8.13 ± 8.10	NS	-7.29 ± 7.44	-8.13 ± 8.10	NS	-8.13 ± 8.10	NS	
<i>Angular measurements</i>												
H-Go/H-Me	136.14 ± 18.06	133.08 ± 13.50	NS	133.08 ± 13.50	134.87 ± 17.54	NS	136.14 ± 18.06	134.87 ± 17.54	NS	134.87 ± 17.54	NS	
H-Me-Go	18.56 ± 8.41	19.24 ± 7.47	NS	19.24 ± 7.47	20.36 ± 11.22	NS	18.56 ± 8.41	20.36 ± 11.22	NS	20.36 ± 11.22	NS	
H-Gn-Go	18.30 ± 7.85	18.73 ± 6.83	NS	18.73 ± 6.83	19.80 ± 10.00	NS	18.30 ± 7.85	19.80 ± 10.00	NS	19.80 ± 10.00	NS	
Sagittal												
<i>Linear measurements</i>												
H-RGn	43.82 ± 4.44	43.92 ± 5.44	NS	43.92 ± 5.44	44.63 ± 7.03	NS	43.82 ± 4.44	44.63 ± 7.03	NS	44.63 ± 7.03	NS	
H-Me	48.94 ± 4.76	49.10 ± 5.71	NS	49.10 ± 5.71	49.60 ± 7.39	NS	48.94 ± 4.76	49.60 ± 7.39	NS	49.60 ± 7.39	NS	
H-Gn	53.14 ± 5.02	53.41 ± 5.95	NS	53.41 ± 5.9	53.94 ± 6.91	NS	53.14 ± 5.02	53.94 ± 6.91	NS	53.94 ± 6.91	NS	
H-B	57.56 ± 5.35	57.95 ± 5.65	NS	57.95 ± 5.65	59.02 ± 5.40	NS	57.56 ± 5.35	59.02 ± 5.40	NS	59.02 ± 5.40	NS	
H-N (FH)	63.62 ± 9.51	65.47 ± 9.18	NS	65.47 ± 9.18	66.20 ± 9.46	NS	63.62 ± 9.51	66.20 ± 9.46	NS	66.20 ± 9.46	NS	
H-Cv3ia Horizontal	39.09 ± 5.39	36.76 ± 4.59	NS	36.76 ± 4.59	41.26 ± 5.18	<0.001*	39.09 ± 5.39	41.26 ± 5.18	NS	41.26 ± 5.18	NS	
H-Cv3ia	40.42 ± 5.50	37.80 ± 4.70	NS	37.80 ± 4.70	42.71 ± 5.75	0.001*	40.42 ± 5.50	42.71 ± 5.75	NS	42.71 ± 5.75	NS	
H-Cv4ia	46.22 ± 5.80	44.79 ± 5.40	NS	44.79 ± 5.40	48.29 ± 4.61	0.036*	46.22 ± 5.80	48.29 ± 4.61	NS	48.29 ± 4.61	NS	
H-Eb	16.52 ± 3.74	14.28 ± 2.96	<0.001*	14.28 ± 2.96	17.21 ± 3.72	<0.001*	16.52 ± 3.74	17.21 ± 3.72	NS	17.21 ± 3.72	NS	
H-PPW	35.22 ± 5.23	32.70 ± 3.91	NS	32.70 ± 3.91	37.77 ± 6.14	<0.001*	35.22 ± 5.23	37.77 ± 6.14	<0.001*	37.77 ± 6.14	<0.001*	
<i>Angular measurements</i>												
H-S-N	89.23 ± 4.55	92.07 ± 5.05	0.009*	92.07 ± 5.05	89.02 ± 5.58	0.009*	89.23 ± 4.55	89.02 ± 5.58	NS	89.02 ± 5.58	NS	
Ratios												
H-MP/Cv3ia-Me	0.17 ± 0.08	0.19 ± 0.07	NS	0.19 ± 0.07	0.18 ± 0.08	NS	0.17 ± 0.08	0.18 ± 0.08	NS	0.18 ± 0.08	NS	
H-Me/Cv3ia-Me	0.56 ± 0.05	0.57 ± 0.04	NS	0.57 ± 0.04	0.54 ± 0.05	NS	0.56 ± 0.05	0.54 ± 0.05	NS	0.54 ± 0.05	NS	
H-Cv3ia/Cv3ia-Me	0.46 ± 0.05	0.44 ± 0.040	NS	0.44 ± 0.040	0.47 ± 0.06	0.017*	0.46 ± 0.05	0.47 ± 0.06	NS	0.47 ± 0.06	NS	

M: Males; F: Females; NS: Nonsignificant differences; * Statistically significant differences between classes

Table 4: Correlation between anthropometric and hyoid variables

Hyoid variables	Correlation	Weight	Height	Body mass index	Neck circumference
<i>Vertical</i>					
<i>Linear measurements</i>					
H-SN	Pearson correlation	0.641**	0.762**	0.283**	0.550**
	Sig. (2-tailed)	0	0	0.002	0
H-S	Pearson correlation	0.644**	0.760**	0.291**	0.561**
	Sig. (2-tailed)	0	0	0.001	0
H-PP	Pearson correlation	0.606**	0.696**	0.291**	0.534**
	Sig. (2-tailed)	0	0	0.001	0
H-PNS	Pearson correlation	0.601**	0.687**	0.293**	0.540**
	Sig. (2-tailed)	0	0	0.001	0
H-MP	Pearson correlation	0.286**	0.389**	0.099	0.261**
	Sig. (2-tailed)	0.002	0	0.287	0.004
H-FH	Pearson correlation	0.621**	0.702**	0.308**	0.548**
	Sig. (2-tailed)	0	0	0.001	0
H-Cv3iaRgn	Pearson correlation	0.327**	0.439**	0.108	0.281**
	Sig. (2-tailed)	0	0	0.244	0.002
H-BaN	Pearson correlation	0.628**	0.709**	0.299**	0.512**
	Sig. (2-tailed)	0	0	0.001	0
H-Tg Dorsum	Pearson correlation	0.530**	0.514**	0.325**	0.465**
	Sig. (2-tailed)	0	0	0	0
H-Cv3ia Vertical	Pearson correlation	-0.366**	-0.438**	-0.163	-0.353**
	Sig. (2-tailed)	0	0	0.080	0
<i>Angular measurements</i>					
H-Go/H-Me	Pearson correlation	-0.140	-0.214*	-0.035	-0.106
	Sig. (2-tailed)	0.131	0.020	0.704	0.251
H-Me-Go	Pearson correlation	0.239**	0.375**	0.044	0.242**
	Sig. (2-tailed)	0.009	0	0.637	0.008
H-Gn-Go	Pearson correlation	0.241**	0.383**	0.042	0.251**
	Sig. (2-tailed)	0.008	0	0.654	0.006
<i>Sagittal</i>					
<i>Linear measurements</i>					
H-RGn	Pearson correlation	0.154	0.076	0.159	0.090
	Sig. (2-tailed)	0.095	0.416	0.086	0.330
H-Me	Pearson correlation	0.116	0.026	0.144	0.023
	Sig. (2-tailed)	0.210	0.777	0.119	0.804
H-Gn	Pearson correlation	0.135	0.050	0.150	0.010
	Sig. (2-tailed)	0.144	0.594	0.106	0.914
H-B	Pearson correlation	0.330**	0.302**	0.217*	0.213*
	Sig. (2-tailed)	0	0.001	0.018	0.020
H-N (FH)	Pearson correlation	0.120	0.092	0.084	0.059
	Sig. (2-tailed)	0.197	0.325	0.369	0.529
H-Cv3ia Horizontal	Pearson correlation	0.591**	0.458**	0.435**	0.496**
	Sig. (2-tailed)	0	0	0	0
H-Cv3ia	Pearson correlation	0.605**	0.499**	0.423**	0.523**
	Sig. (2-tailed)	0	0	0	0
H-Cv4ia	Pearson correlation	0.432**	0.288**	0.354**	0.345**
	Sig. (2-tailed)	0	0.002	0	0
H-Eb	Pearson correlation	0.502**	0.414**	0.341**	0.347**
	Sig. (2-tailed)	0	0	0	0
H-PPW	Pearson correlation	0.639**	0.539**	0.446**	0.542**
	Sig. (2-tailed)	0	0	0	0
<i>Angular measurements</i>					
H-SN	Pearson correlation	-0.296**	-0.364**	-0.118	-0.255**
	Sig. (2-tailed)	0.001	0	0.204	0.005
<i>Ratios</i>					
H-MP/Cv3ia-Me	Pearson correlation	0.161	0.308**	-0.008	0.167
	Sig. (2-tailed)	0.083	0.001	0.933	0.071
H-Me/Cv3ia-Me	Pearson correlation	-0.410**	-0.360**	-0.266**	-0.407**
	Sig. (2-tailed)	0	0	0.004	0
H-Cv3ia/Cv3ia-Me	Pearson correlation	0.358**	0.362**	0.195*	0.368**
	Sig. (2-tailed)	0	0	0.035	0

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed)

Cv3ia-Me showed significant negative correlations with both weight and height, whereas H-Go/H-Me angular measurement correlated only with height.

DISCUSSION

Data from literature for healthy male and female adults of different ethnicities and gender ($BMI \leq 28 \text{ kg/m}^2$; age ≤ 50 years) were taken with comparable inclusion criteria to that of the present study. A protocol for X-rays³⁴ was set to standardize the technique and reduce the drawbacks mentioned by Graber³ in regard to factors that influence the hyoid position, such as slight changes in the head and the cervical spine position as well as the state of functional activity during X-ray acquisitions. Consequently, the movement and activity of the soft tissues and the hyoid bone were limited.

Ethnicity and Gender

Vertical Measurements

The vertical hyoid bone position was extensively studied as the linear distance along a perpendicular from H to MP. The MP was considered as a reference line in most investigations of the hyoid position in the vertical dimension. In cephalometric airway assessment, the Go-Me,^{4,17,36-43} as MP was the most widely used, followed by Go-Gn.⁴⁴⁻⁴⁹ Therefore, H-MP distance would have greater values when Go-Gn is considered, since Gn is anatomically in a more coronal position than Me. To facilitate comparison, the MP used in the present study was Go-Me.

The H-MP value of 15.83 ± 6.15 in the Lebanese sample was greater when compared with 13.61 ± 4.84 in the Turkish healthy adult sample of Malkoc et al.³⁷ For the same age range, Lee et al⁴⁰ found in Korean adult subjects (36.7 ± 14.6 years) smaller H-MP values of 12.52 ± 4.87 . Values of 14.9 ± 2.8 were also found in an adult Indian origin sample by Thapa et al⁴³ and 13.16 ± 4.56 in healthy Brazilian subjects by Piccin et al.⁵⁰ Seto et al⁵¹ found in an Australian Caucasian group (40 ± 2 years) an H-MP of 14.44 ± 1.23 , while similar results in different samples of Turkish population were found for the same age group; 14.99 ± 3.46 by Akpınar et al⁴² (42.72 ± 10.61 years), 15.0 ± 5.7 by Yucel et al³⁹ (49.0 ± 7.8 years), and 15.11 ± 5.75 by Adisen et al⁵² (18–50 years). Korean values for H-MP were shown to be the smallest among Lebanese, Turkish, Indian, Australian, Croatian, and Brazilian population. When Go-Gn was used as MP, H-MP values of 14.9 ± 3.6 was found in a Thai population (47.7 ± 9.9 years) by Banhiran et al.⁴⁸ In a healthy Turkish population, Kurt et al⁴⁷ and Gungor et al⁴⁹ found greater values of 17.97 ± 4.74 (age range of 24–35) and 19.75 ± 6.57 (48.06 ± 9.74 years) respectively. In addition, a study by Chang and Shiao⁴⁶

found an H-MP of 18.9 ± 9.8 in a Chinese population (51.3 ± 14.7 years). This implies when Go-Gn is considered, Thai values for H-MP were smaller in comparison to Turkish and Chinese population. Whether Go-Gn or Go-Me was used as MP, H-MP values were dependent on mandibular rotation in different ethnicities that causes the base of the tongue to be positioned more inferiorly and posteriorly, affecting in the same manner the position of the hyoid. When gender differences were studied, related data showed greater values of H-MP in males than females in different ethnic groups.^{4,44} In Taiwanese population,⁴ both values of 14.46 ± 6.12 in males and 10.30 ± 5.24 in females were found to be smaller than the Lebanese sample values of 18.37 ± 6.52 in males and 14.09 ± 5.26 in females. Smith and Battagel⁵³ found greater values of H-MP for both males (19.8) and females (20.1), in British Caucasian adults. Values found by Lee et al⁴⁴ were considered to be higher in Blacks, Caucasians, and Hispanics than those of the present study (males: Blacks 23.78 ± 6.92 , Caucasians 25.52 ± 6.58 , Hispanics 20.13 ± 7.53 ; females: Blacks 19.22 ± 7.08 , Caucasians 19.20 ± 5.44 , Hispanics 17.00 ± 7.38). Differences between our sample and Blacks, Caucasians, and Hispanics from Lee et al⁴⁴ could be explained by the discrepancies in the age group (age ranged between 18 and 65) and the use of Go-Gn as MP. When H-MP values of 18.4 ± 6.5 in male adults of the present study was compared with other male ethnic groups, greater values of 22.5 ± 5.7 were found in Caucasian (41.8 ± 9.0 years) by Battagel et al,³⁸ yet smaller value of 15.46 ± 5.69 by Vidovic et al⁵⁴ in Croatian (37.25 ± 14.38 years). When Genta et al⁵⁵ studied the Japanese/Brazilian adult males and Schorr et al⁵⁶ compared them with white, H-MP values were 14.7 ± 7.9 (47.5 ± 13.5 years), 15.0 ± 7.9 (47.2 ± 13.3 years), and 17.2 ± 8.0 (47.8 ± 12.5 years) respectively. Different results were observed in three separate studies in an Asian Japanese adult male population with the same age group.^{36,57,58} Smaller values of 14.0 ± 6.4 were observed by Sakakibara et al³⁶ (36.2 ± 11.4 years) and 14.0 ± 5.4 by Miyao et al⁵⁷ (48.3 ± 10.9 years), while those of Takai et al⁵⁸ were 18.4 ± 7.1 (38.3 ± 14.1 years) that are found to be similar to this study.

Other measurements were investigated to improve the vertical assessment of the hyoid bone position, such as H-PP. The overall population values present in the literature for H-PP were found to be far edged between the Lebanese sample with a value of 67.49 ± 9.08 and 33.1 ± 2.9 in a comparable Thai sample by Banhiran et al,⁴⁸ while values of 63.8 ± 8.6 obtained by Johal et al⁴¹ in a Caucasian male and female adult group were closer to the values from our sample. The variations observed in these studies can be explained by ethnic differences, maxillary vertical position, and palatal plane orientation in different facial types. H-PP showed higher values of 75.57 ± 6.37 in males

when compared with 61.94 ± 5.96 in females. In British Caucasians, Battagel et al³⁸ found an H-PP of 71.2 ± 5.3 in males (41.8 ± 9.0 years). Smith and Battagel⁵³ demonstrated an H-PP value of 73.4 ± 19.8 in males, and 60.2 ± 21.7 in females, that aged between 29 and 61 years, and 28 and 60 years respectively. When males and females were studied separately, no significant differences were found for H-PP within the Caucasian ethnic groups.

The H-PNS value for the overall Lebanese sample was found to be 68.40 ± 8.73 . Similar results of 66.81 ± 8.19 were found by Calvão in a Brazilian control group (mean age 20 years 7 months).⁵⁹ In the present study, the vertical distance H-PNS showed values of 76.00 ± 6.30 in males greater than 63.19 ± 5.87 in females. Sheng et al⁴ found in a Taiwanese group (7–27 years) an H-PNS of 71.66 ± 5.40 in males and 60.36 ± 4.71 in females. The vertical position of PNS, related to the facial type, could be held responsible for the variation in H-PNS measurements in different ethnicities.

The vertical distance H-FH was calculated and showed results of 101.17 ± 8.14 in men that was greater than the value of 84.87 ± 7.32 obtained in women, implying a more inferiorly positioned tongue and hyoid bone in men. Shen et al⁶⁰ demonstrated on lateral cephalograms similar differences in normal Chinese adult males and females (18–25 years) of 78.8 ± 7.9 and 70.4 ± 4.9 respectively. Samman et al⁶¹ reconfirmed the gender differences in another healthy Chinese adult sample and found values of 92.4 ± 6.3 in males and 78.5 ± 5.8 in females, aged between 18 and 35 years, having a normal skeletal facial profile. Similar differences were found in the study of Shastri et al⁶² performed on North Indian subjects with 94.4 ± 6.4 in males and 79.5 ± 5.8 in females.

The H-S value of 114.84 ± 12.81 for the overall Lebanese population was found. Similar results of 112.61 ± 10.88 by Galvão⁵⁹ were obtained in a control group of Brazilian males and females (mean age 20 years 7 months). The vertical distance H-S was calculated and showed values of 126.63 ± 9.42 in males that was greater than 106.76 ± 7.42 in females. Vidovic et al⁵⁴ found smaller values of 37.25 ± 14.38 years for Croatian males in comparison to 112.0 ± 15.9 in females. The cranio-maxillary plane (FH) and the anterior cranial base (SN) could be affected by the facial pattern of the subjects. Conclusions for the vertical position of the hyoid bone cannot be drawn without an assessment of the vertical facial type, that is, partially responsible for H-FH and H-S measurements.

The overall H-Cv3iaRGn value obtained was 2.26 ± 6.24 . In males and females in a Turkish sample (18–24 years), Malkoc et al³⁷ found a value of 12.03 ± 5.52 that implies a lower hyoid bone position when compared with values of the present study. H-Cv3iaRGn is affected by the orientation of Cv3iaRGn plane, due to the type of

mandibular rotation of the subjects. During X-ray acquisitions, the head position in the cephalostat may affect that of the cervical spine, in specific the Cv3ia landmark.

The hyoid parameters, related to the vertical position (H-SN, H-MP, H-PP, H-PNS, H-FH, H-S, H-Cv3iaRgn), presented some discrepancies, when compared with the previously cited studies. This is explained by differences in age groups and MP definition. In addition, the changes in the skeletal facial patterns and mandibular rotation within diverse ethnicities caused the base of the tongue to be positioned more inferiorly and posteriorly, followed by the hyoid. Therefore, the vertical distance from H to any horizontal and canted reference planes, such as SN, FH, ANS-PNS, MP and Cv3ia-RGn, were also affected. During X-ray acquisitions, where reproducibility is required, the head must be cautiously placed in a natural position to avoid deviations of the cervical spine. Which if occurs, the Cv3ia landmark will be modified, hence influencing the H-Cv3iaRGn distance. Therefore, facial type identification is mandatory in assessing the vertical position of the hyoid bone.

Sagittal Measurements

The horizontal hyoid bone position was assessed by different linear, angular, and ratio measurements in the present study.

In the studied sample, the overall H-RGn value was 44.02 ± 5.45 . Smaller values of 38.83 ± 5.45 were obtained by Malkoc et al³⁷ in a Turkish sample, with an age range of 18 to 24 years. The H-RGn value of 43.81 ± 5.38 for males was less than that (44.17 ± 5.53) for females, with no statistically significant difference ($p = 0.722$).

The H-Me value of the Lebanese sample was 49.15 ± 5.74 . Similar results of 47.53 ± 4.64 were demonstrated by Galvão⁵⁹ in a control group of Brazilian males and females, with a mean age of 20 years and 7 months. In the present study, females showed greater values of 49.64 ± 5.72 for H-Me than 48.43 ± 5.75 in males, with no statistically significant difference ($p = 0.265$). Smith and Battagel⁵³ showed values of 46.4 ± 23.9 and 44.0 ± 11.8 in Caucasian adult males and females respectively (age range of 29–61 years for males, while it was 28–60 years for females).

No statistically significant difference ($p = 0.054$) was found between males and females, with H-B values of 59.14 ± 5.1 and 57.15 ± 5.72 respectively. The value of 59.14 ± 5.1 in males was greater, compared with 51.1 ± 5.9 obtained by Battagel et al³⁸ in adult British Caucasian males.

Smaller values of 39.24 ± 5.43 for H-Cv3ia in the Lebanese sample were larger than 34.55 ± 4.30 obtained by Piccin et al⁵⁰ in healthy Brazilian subjects (41.19 ± 11.20 years), yet smaller than 41.75 ± 5.43 by Adisen et al⁵² in a

Turkish sample, aged between 18 and 50 years. Statistical significance was observed for H-Cv3ia when comparing this study values of 43.3 ± 4.98 in males and 36.57 ± 3.92 in females. Smaller values of 40.2 ± 20.1 for males, and 32.5 ± 14.4 for females were obtained by Smith and Battagel⁵³ in British Caucasian adults (age range of 29–61 years for males, and 28–60 years for females).⁵³ Battagel et al³⁸ found comparable results of 35.9 ± 3.1 in British Caucasian adult males (41.8 \pm 9.0 yrs). In addition, Sheng et al⁴ showed equivalent values of 35.74 ± 2.87 in females and 41.08 ± 3.69 in males, in Taiwanese subjects (7–27 years) like Vidovac et al⁵⁴ that showed 35.06 ± 2.64 in Croatian males (37.25 \pm 14.38 years).

The overall H-Eb value obtained in the Lebanese population was 15.33 ± 3.51 , although a greater value of 20.3 ± 4.8 was found by Johal et al⁴¹ in a Caucasian male and female adult group. The distance from H to Eb was calculated as 17.43 ± 3.75 in males, being greater than 13.89 ± 2.48 in females. Sheng et al⁴ found in Taiwanese subjects the H-Eb values of 15.61 ± 3.08 in males and 13.94 ± 2.33 in females (7–27 years).

The sagittal distance H-PPW of the present study showed statistically significant difference between values of 38.02 ± 4.64 for males and 31.45 ± 3.30 for females. Vidovic et al⁵⁴ showed comparable values of 35.78 ± 2.49 in Croatian males (37.25 \pm 14.38 years).

The measurements defining the anteroposterior location of the hyoid showed a more posterior position in the female group. Statistically significant smaller values in females than in males was observed for H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, and H-PPW, which is explained by their more retrognathic mandible position. Correspondingly, greater values for H-RGn and H-Me were found in females when compared with males. Yet, those differences were not significant.

Skeletal Classes

Five of ten sagittal linear measurements defining the anteroposterior position of the hyoid bone (H-RGn, H-Me, H-Gn, H-B, H-N (FH)) were not affected by the skeletal pattern. This finding was in agreement with earlier studies.⁶³⁻⁶⁸ The remaining five measurements (H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW), located posterior to the hyoid bone, presented significant correlations between classes, mainly II and III. All the vertical linear and angular measurements, including distances from H-FH and H-SN, did not show any statistically significant correlation between classes, except for the H-BaN vertical variable that showed correlation to classes II and III solely. In reference to the true horizontal line, represented by FH, SN is considered almost parallel to it, while BaN is canted downward posteriorly (Fig. 1). The more posterior position

of the hyoid bone in class II resulted in a shorter distance H-BaN, unlike a greater one, in a more anteriorly located hyoid bone in class III.⁸ This common correlation between hyoid variables and different classes in the present study fall under the morphological variations of craniofacial and skeletal structures, specifically in classes II and III. Those significant findings in regard to the classes were in agreement with Yamaoka et al,¹³ Galvão,⁵⁹ Jose et al,¹⁸ using Bibby and Preston²⁰ analysis. In contrary, controversial results were found by Kuroda et al.¹⁵ The anteroposterior position of the hyoid bone is the result of suprahyoid muscles activity, related to the clockwise and counter-clockwise mandibular rotations. In an anterior rotation, the hyoid is in an upward and anterior position. While in posterior, it is located more retro-inferior. Therefore, the mandibular rotation impact is far more important than classes in dictating the sagittal hyoid position.²⁵

Anthropometrics

Anthropometric data and gender differences of the Lebanese sample were represented earlier in an airway-related study.³⁴ The overall mean BMI was 23.2 ± 3.5 . Average figures were 24.6 ± 3.3 and 22.2 ± 3.2 for males and females respectively. Weight, height, BMI, and NC measurements were significantly greater in males than in females.³⁴ The relative differences in skeletal classes for the studied sample were described by Daraze et al,³⁴ when assessing the upper airway dimensions cephalometrically, in healthy Lebanese subjects. Few statistically significant differences were found in BMI between the three classes, while body height, weight, and NC were significantly greater in class III when compared with classes I and II.

The vertical hyoid position represented by H-SN, H-S, H-PP, H-PNS, H-MP, H-FH, H-Cv3iaRgn, H-BaN, H-Tg Dorsum and H-Cv3ia Vertical was strongly correlated to the height of individuals, which interacts intimately with skeletal facial types creating harmony. Weight followed height and NC, unlike BMI, was the least correlated. Comparable values were obtained when correlating the sagittal measurements (H-B, H-Cv3ia Horizontal, H-Cv3ia, H-Cv4ia, H-Eb, H-PPW) to height, BMI, and NC. Weight correlated the most with sagittal linear measurements. This highlights the strong impact of the following anthropometric factors on the vertical and sagittal dimensions. Height displayed more correlation with the vertical measurements, while weight correlated more with those of the sagittal.

Usually, clinicians record the BMI (weight/height²) and NC to check if their patients' values are within the normal range. Results of this study tend to redirect the impact of height and weight as separate entities, on the measurements, to assess the hyoid bone position in the vertical and sagittal dimension respectively. Useful

information can be derived from hyoid bone position in this study regarding the assessment of airway-related measurements. Variations in the hyoid bone position can occur under standardized conditions, even in the same person. Discrepancies between studies are justified by differences in populations, measurements, procedures, classes, craniofacial patterns, and the anthropometric heterogeneity in gender, age, weight, height, BMI, and NC.

CONCLUSION

- Cephalometric norms for the hyoid bone position in the Lebanese population have been established in this study.
- Anthropometric conclusions:
 - Sexual dimorphism was demonstrated.
 - Differences were observed within diverse ethnicities where related facial type identification is mandatory in assessing the vertical position of the hyoid bone.
 - The vertical hyoid position was strongly correlated to the height, which interacts intimately with skeletal facial types, followed by weight, NC, and then BMI.
 - The sagittal hyoid position was strongly correlated to the weight of individuals, followed by height, NC, and BMI similarly.
 - The BMI correlated the least to both vertical and sagittal hyoid measurements.
 - As a clinical relevance, the impact of height and weight as separate entities should be considered in assessing the hyoid position.
- Skeletal patterns did not influence the sagittal and vertical hyoid position.

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