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Radiological Morphometric Study of the Hyoid Bone using Three-Dimensional Computed Tomography (3D-CT) Scans

Estudio Morfométrico Radiológico del Hueso Hioides Mediante Tomografía Computarizada Tridimensional (3D-CT)

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SUMMARY: Hyoid bone measurements have been proposed to vary between different genders and age groups. The aim of the study is to study hyoid morphometrics among Jordanian patients. 3D-CT scans of 637 patients were analyzed. Ten parameters of hyoid bone were measures, including the anteroposterior length, length of greater horns (right and left), height of greater horns (right and left), width of hyoid body, height of hyoid body, the distance between the midpoints of the posterior ends of the greater horns of the hyoid bone, the angle between right and left greater horns, and the distance of the hyoid bone to the vertebral column. Also, vertebral level, fusion rank, morphology of hyoid body lingula, and shape of hyoid bone were documented. All hyoid dimensions were longer in males, but greater horns angle was wider in females. In patients younger than 30 years, the parameters are the smallest with the widest angle. The distance from hyoid to vertebral column is higher in males (30-49) years of age. No fusion between hyoid body and greater horns was observed in patients younger than 10 years, but fusion (unilateral or bilateral) was found in only 73.2 % of patients ≥ 70 years. The hyoid was mostly at vertebra C3 level and "U" shaped. The lingula shape was mostly "Scar" in males (especially ≥ 50 years) and "Nothing" in females (especially < 50 years). The maximum growth of hyoid dimensions is before age of 30 years. Fusion between hyoid body and greater horns was not seen in patients younger than 10 years. Otherwise, the hyoid features failed to predict age or gender in our sample. Furthermore, 3D-CT scan is an excellent tool to assess the anatomy of head and neck region.

KEY WORDS: Hyoid; Morphometrics; Age; Sex.

INTRODUCTION

The human neck is anatomically composed of bones, muscles, ligaments, soft tissues, and neurovascular structures. These components interplay for performing the required functions of movement, speech, swallowing, and respiration. The hyoid bone position helps in performing these actions. It differs from other bones in that it does not articulate with other bones, but acts like origin and insertion of different muscles which are grouped into suprahyoid and infrahyoid muscles (Fakhry *et al*., 2013).

The hyo-laryngeal complex is an integral part of the aerodigestive tracts. Any change in the anatomy or function of the complex can affect both respiration and swallowing. In addition, the relative position of bones and cartilages to the mandible, skull base, and vertebral column has been reported to be of significant clinical value in many reports (Bibby & Preston, 1981).

Sex and age determination in cadaveric bodies is sometimes challenging. Many bones are usually studied

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to accomplish this target, such as hips (Spradley & Jantz, 2011). There are many studies that corelate changes in hyoid bone morphometrics with the sex and age differences. These are measured using different techniques, including direct cadaveric measurements, X-ray images, and computed tomography (CT) scans.

The aim of our study is to measure different hyoid dimensions, and to detect differences between both sexes and between various age groups. In addition, some morphological features are reported, and their prevalence is documented.

MATERIAL AND METHOD

The 650 consecutive computed tomography (CT) scans of cervical spine and CT scans of neck that were performed for different patients in Specialty Hospital were retrospectively included in the study. Thirteen images were excluded due to history of neck trauma, neck surgery, or laryngeal neoplasms. Thus, images of 637 patients were enrolled; 374 males and 263 females (mean age 43.4458 ± 19.32072 years (SD); age range 1.2-89 years). The age was categorized into groups; (1-29) years, (30-49) years, (50-69) years, and ≥70 years. The images were retrieved from the hospital's "Image Picture Archiving and Communication System". Multislice spiral CT scans were obtained with a multidetector 512 slice GE Revolution CT using the following parameters: 120-140 kV, smart mAs = 125-330 mAs, slice thickness = 1 mm, matrix = 512x512, collimation = 40 mm with slice thickness 0.625. Pitch = 0.5 FOV (Field of View) (150-200). A 3D reconstruction was created from scanned images using NovaPACS diagnostic Viewer (Version 8.7) programme. Different parameters were retrospectively measured by radiology residents, and the data were collected and saved to excel sheet.

Ten parameters of the hyoid bone were measured. These are the anteroposterior length of hyoid bone, length of greater horns (right and left), height of greater horns (right and left), width of hyoid body, height of hyoid body, the distance between the midpoints of the posterior ends of the greater horns of the hyoid bone, the angle between right and left greater horns, and the distance of the hyoid bone to the vertebral column. The latter is the distance from the greater horn's posterior end to the vertebral column on the line drawn parallel to its long axis. Also, the vertebral level of the hyoid bone was documented (Fig. 1).

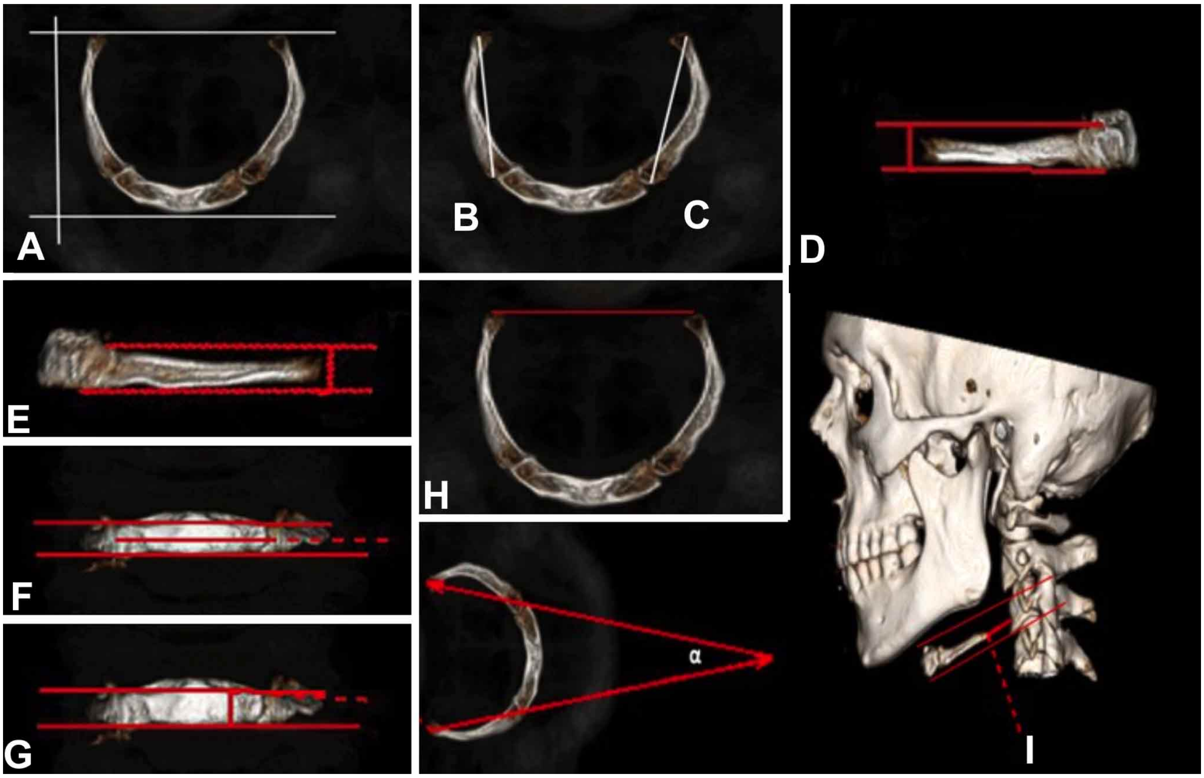


Fig. 1 Dimensions of the hyoid bone. A: Antero-posterior length of hyoid bone. B: Length of right greater horn. C: Length of left greater horn. D: Height of right greater horn. E: Height of left greater horn. F: Width of hyoid body. G: Height of hyoid body. H: The distance between the midpoints of the posterior ends of greater horns. I: The distance between posterior end of hyoid and vertebral column. a: The angle between greater horns.

Fusion status between the hyoid body and greater horns was reported. We adopted Fisher *et al*. (2016) classification of fusion patterns. They were classified into many ranks; Rank 0 (bilateral distant non-fusion), Rank 1 (bilateral non-fusion), Rank 2 (partial or unilateral fusion), and Rank 3 (bilateral fusion) (Fig. 2).

In addition, the Lingula-related morphological features of the hyoid bone were documented. Type A is when lingula developed at the center of upper peripheral hyoid body (Development); Type B is when the scar of the lingula was identified (Scar); and Type C is when the lingula was not identified (Nothing) (Fig. 3). The shape of the hyoid bone is also classified into "U", "V", and "horseshoe" types (Fig. 4).

The ethical approval was obtained from the Institutional Review Board (Approval Code 5/1/T/109464). This study followed the principles of the Declaration of Helsinki. The data were entered and analyzed using the Statistical Package for Social Science (SPSS version 20). To determine the frequency of the vertebra level, The morphological appearance for each decade and both sexes. The association of fusion ranks with sex and age group were examined using Chi-square tests of independence. Kruskal-Wallis test was used for comparison between the decades, because more than two independent groups were which were not normally distributed. The independent samples T-test was used for normally distributed data. One-way ANOVA models were used to investigate the association of sex, age, and the measurements of hyoid bone. A P-value of < 0.05 was considered statistically significant.

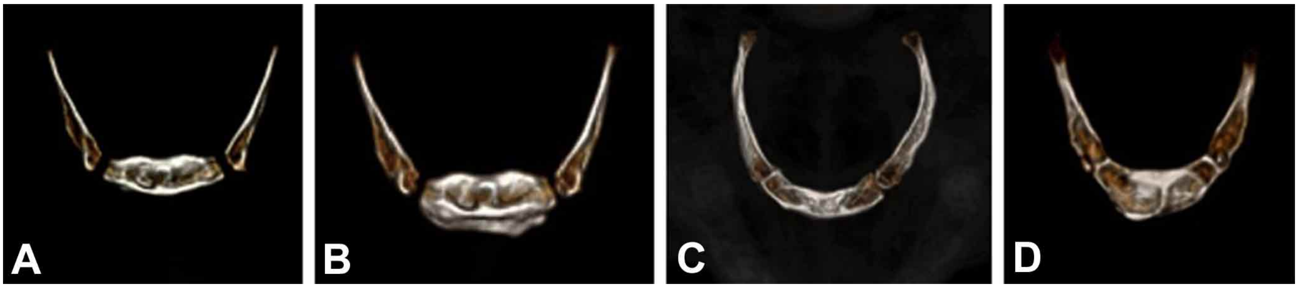


Fig. 2 Fusion Rank between hyoid body and greater horns. A: Rank 0. B: Rank 1. C: Rank 2. D: Rank 3.

Fig. 3 Shape of Lingula. A: Development. B: Scar. C: Nothing.

Fig. 4 Shape of the Hyoid. A: "U" shape. B: "V" shape. C: "Horseshoe" shape

RESULTS

A total of 637 CT images were studied and analyzed, and 41.29 % were for female patients ($p > 0.05$) (Fig. 5). When the parameters were compared according to sex, males had significantly longer dimensions except for the angle between greater horns, which was more in females ($p < 0.05$). In addition, although the measurements were significantly smaller in the youngest age group (1-29 years), the angle between greater horns was widest in the same group ($p < 0.05$) (Fig. 6). Further comparison between both sexes for specific age groups was performed for these dimensions, and they were all longer in males significantly, except for wider greater horn angles in females. In addition, the distance of the hyoid bone to the vertebral column was not significantly different between both sexes in all age groups except in (30-49) years age group, which was more in males (Tables I, II, and III).

The hyoid bone level was more prevalent at C3 level in both sexes (67.4 % in males vs 70.5 % females), all age groups, and all sex-specific age groups. The second most common level was C4 in males (24.6 %), and C2 in females (18.2 %). The same finding was detected in all age groups, except for C2 level in (1-29) years age group (16 %). When sex-specific age groups were compared, C4 was the second most common level in males in all age groups, and C2 in females younger than 50 years, and C4 in females who are ≥50 years.

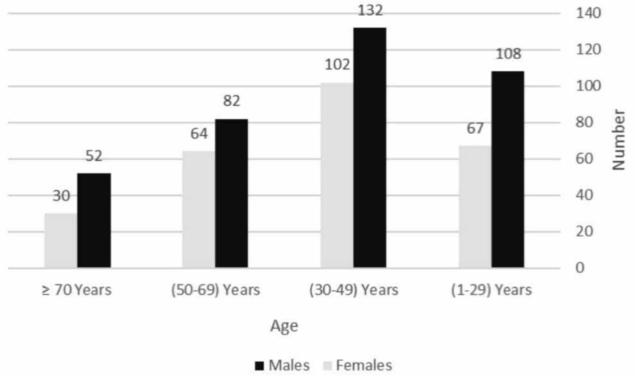


Fig. 5. Sex distribution among different age groups.

In addition, sex did not have an impact on fusion rank between body and greater horn in all age groups, either in general or in specific groups. However, the most commonly found frequency was Rank 1 (bilateral non-fusion) in all age groups except for rank 3 (bilateral fusion) in age group ≥ 70 years in both sexes. Rank 0 (bilateral distance non-fusion) was the second most prevalent rank in age group (1-29) years (31.4 %), but was the least prevalent in patients who are ≥ 30 years (Fig. 7).

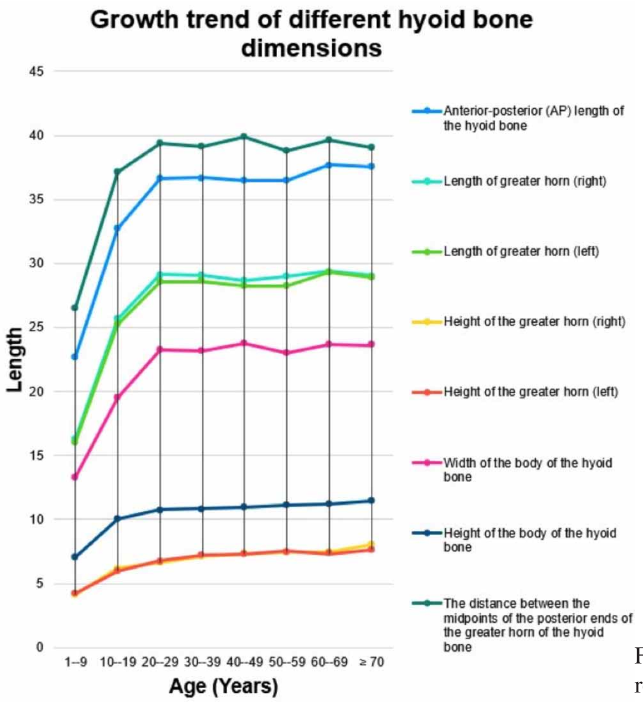
Furthermore, there was no significant difference in the lingula-related morphological features of hyoid bone when compared according to sex, age groups, or sex-specific age groups. Nevertheless, it was noticed that the most

Table I. Comparing the measurements between males and females.

Measurements	Total mean± SD	Males mean± SD	Females mean± SD	P-value
Anterior-posterior (AP) length of the hyoid bone	36.2± 5.1	38.41 ±4.6	33.15 ±3.9	0.000
Length of greater horn (Right)	28.49 ±4.2	30.05 ±3.9	26.27 ±3.4	0.000
Length of greater horn (Left)	28.07± 4.2	29.58 ±3.9	25.93 ±3.6	0.000
Height of the greater horn (Left)	7.09 ± 1.8	7.49 ± 1.9	6.52 ± 1.6	0.000
Height of the greater horn (Right)	7.14 ± 1.8	7.51 ±1.9	6.61 ± 1.7	0.000
Width of the body of the hyoid bone	22.92 ± 3.6	24.54 ± 3.1	20.64 ±2.8	0.000
Height of the body of the hyoid bone	10.85 ± 2.1	11.45 ± 1.9	10.00± 2.0	0.000
The distance between the midpoints of the posterior ends of the greater horn of the hyoid bone	38.85 ± 5.7	40.41 ± 5.7	36.64 ± 4.9	0.000
The distance of the hyoid bone to the vertebral column (The distance from the greater horn's posterior end to the vertebral column on the line drawn parallel to its long axis)	3.33 ± 3.0	3.57 ± 3.1	3.00± 2.8	0.019
Angle of right and left greater horn (The angle between greater horn by connecting the lines passing through the midpoints of the anterior and posterior ends of the greater horn)	31.96 ± 10.3	30.03 ± 10.3	34.69± 9.6	0.000
Vertebral level of the hyoid bone, N (%)				
C2	70 (11.0%)	22 (5.9%)	48 (18.2%)	0.000
C2-3	6 (0.9%)	2 (0.5%)	4 (1.5%)	
C3	438 (68.7%)	252 (67.4%)	186 (70.5%)	
C4	117 (18.3%)	92 (24.6%)	25 (9.5%)	
C3-4	6 (0.9%)	5 (1.3%)	1 (0.4%)	
C5	1 (0.2%)	1 (0.3%)	0 (0.0%)	
Fusion rank between the hyoid body and the greater horn				
Rank 0 (bilateral distance non-fusion)	63 (9.9%)	34 (9.1%)	29 (11.0%)	0.761
Rank 1 (bilateral non-fusion)	298 (46.7%)	172 (46.0%)	126 (47.7%)	
Rank 2 (partial fusion)	129 (20.2%)	79 (21.1%)	50 (18.9%)	
Rank 3 (bilateral fusion)	148 (23.2%)	89 (23.8%)	59 (22.3%)	
The lingula-related morphological features of the hyoid bone				
Development (A, lingula developed at the central upper peripheral hyoid bone)	117 (18.3%)	67 (17.9%)	50 (18.9%)	0.189
Scar (B, the scar of lingula was identified)	268 (42.0%)	168 (44.9%)	100 (37.9%)	
Nothing (C, the lingula was not identified)	253 (39.7%)	139 (37.2%)	114 (43.2%)	
The morphological appearance of the hyoid bone is				
A	431 (67.6%)	250 (66.8%)	181 (68.6%)	0.068
B	175 (27.4%)	99 (26.5%)	76 (28.8%)	
C	32 (5.0%)	25 (6.7%)	7 (2.7%)	

Table II. Comparing the measurements between different age groups.

Measurements	1-29 years mean± SD	30-49 years mean± SD	50-69 years mean± SD	≥ 70 years mean± SD	P-value
Anterior-posterior (AP) length of the hyoid bone	34.58 **± 5.9**	36.60 **± 4.4**	37.05 **± 4.3**	37.53 **± 4.5**	0.000
Length of greater horn (right)	27.24 **± 5.2**	28.87 **± 3.4**	29.17 **± 3.5**	29.06 **± 3.8**	0.000
Length of greater horn (left)	26.76 **± 5.1**	28.42 **± 3.6**	28.74 **± 3.5**	28.91 **± 3.5**	0.000
Height of the greater horn (right)	6.30 **±1.6**	7.24 **±1.8**	7.49 **± 1.7**	8.06 **± 1.9**	0.000
Height of the greater horn (left)	6.38 **± 1.6**	7.25 **± 1.7**	7.43 **± 1.7**	7.63 **± 2.0**	0.000
Width of the body of the hyoid bone	21.61 **± 4.1**	23.47 **± 3.0**	23.34 **± 3.5**	23.61**± 2.8**	0.000
Height of the body of the hyoid bone	10.26 **± 2.0**	10.90 **± 1.8**	11.16 **± 2.4**	11.48 **± 2.1**	0.000
The distance between the midpoints of the posterior ends of the greater horn of the hyoid bone	37.71 **± 6.2**	39.49 **± 5.4**	39.18 **± 5.6**	39.06 **± 5.3**	0.015
The distance of the hyoid bone to the vertebral column (The distance from the greater horn's posterior end to the vertebral column on the line drawn parallel to its long axis)	3.55 **± 2.8**	2.90 **± 2.6**	3.69 **± 3.5**	3.46 **± 3.2**	0.047
Angle of right and left greater horn (The angle between greater horn by connecting the lines passing through the midpoints of the anterior and posterior ends of the greater horn)	33.81**± 10.5**	31.85**± 9.9**	30.87**± 10.5**	30.16 **± 9.9**	0.019
Vertebral level of the hyoid bone					
C2	28 (16.0 %)	29 (12.4 %)	10 (6.8 %)	3 (3.7 %)	0.038
C2-3	2 (1.1 %)	1 (0.4 %)	1 (0.7 %)	2 (2.4 %)	
C3	123 (70.3 %)	159 (67.9 %)	98 (67.1 %)	57 (69.5 %)	
C4	21 (12.0 %)	42 (17.9 %)	35 (24.0 %)	19 (23.2)	
C3-4	0 (0.0 %)	3 (1.3 %)	2 (1.4 %)	1 (1.2)	
C5	1 (0.6 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0)	
The Lingula-related morphological features of the hyoid bone					
Development (A, lingula developed at the central upper peripheral hyoid bone)	38 (21.7 %)	45 (19.2 %)	19 (13.0 %)	15 (18.3 %)	0.153
Scar (B, the scar of lingula was identified)	66 (37.7 %)	90 (38.5 %)	75 (51.4 %)	37 (45.1 %)	
Nothing (C, the lingula was not identified)	71 (40.6 %)	99 (42.3 %)	52 (35.6 %)	30 (36.6 %)	
The morphological appearance of the hyoid bone is					
A	103 (58.9 %)	161 (68.8 %)	106 (72.6 %)	60 (73.2 %)	0.005
B	65 (37.1 %)	64 (27.4 %)	32 (21.9 %)	14 (17.1 %)	
C	7 (4.0 %)	9 (3.8 %)	8 (5.5 %)	8 (9.8 %)	



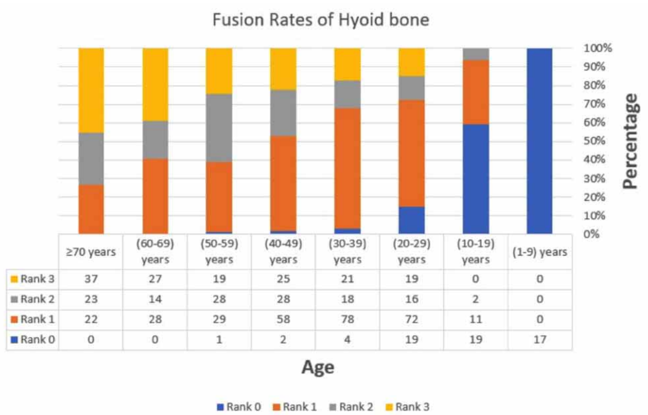


Fig. 7 Fusion rates between hyoid bones and greater horns according to age.

Fig. 6 Length of different hyoid bone dimensions (in millimeters) relative to Age (in years).

Table III. Comparing the measurements between specific age groups according to males and females.

Measurements	1-29 years Males mean± SD	Females mean± SD	P-value	30-49 years Males mean± SD	Females mean± SD	P-value	50-69 years Males mean± SD	Females mean± SD	P-value	≥ 70 years Males mean± SD	Females mean± SD	P-value
Anterior-posterior (AP) length of the hyoid bone	36.63±5.9	31.27±4.3	**0.000**	39.13±3.6	33.33±2.9	**0.000**	39.04±3.8	34.50±3.5	**0.000**	39.29±4.0	34.46±3.5	**0.000**
Length of greater horn (Right)	28.76±5.2	24.80±4.0	**0.000**	30.58±2.9	26.66±2.5	**0.000**	30.70±3.1	27.21±2.9	**0.000**	30.37±3.5	26.77±3.2	**0.000**
Length of greater horn (Left)	28.19±4.9	24.44±4.4	**0.000**	30.22±3.2	26.07±2.7	**0.000**	30.06±3.4	27.05±2.9	**0.000**	30.07±3.1	26.89±3.2	**0.000**
Height of the greater horn (Right)	6.62±1.6	5.78±1.4	**0.001**	7.57±1.7	6.82±1.8	**0.002**	7.88±1.8	6.97±1.5	**0.002**	8.66±1.9	7.02±1.5	**0.000**
Height of the greater horn (Left)	6.67±1.8	5.92±1.5	**0.005**	7.63±1.7	6.75±1.6	**0.000**	7.94±1.7	6.77±1.5	**0.000**	8.18±2.1	6.68±1.4	**0.000**
Width of the body of the hyoid bone	23.18±3.8	19.07±3.1	**0.000**	25.21±2.4	21.20±2.0	**0.000**	25.10±2.7	21.07±2.9	**0.000**	24.73±2.4	21.66±2.4	**0.000**
Height of the body of the hyoid bone	10.79±1.9	9.41±1.9	**0.000**	11.56±1.7	10.05±1.4	**0.000**	11.76±1.9	10.41±2.7	**0.001**	12.05±2.0	10.49±1.8	**0.001**
The distance between the midpoints of the posterior ends of the greater horn of the hyoid bone	39.04±5.8	35.57±6.2	**0.000**	41.41±5.6	37.01±3.9	**0.000**	40.78±5.9	37.13±4.5	**0.000**	40.11±5.1	37.23±5.0	**0.016**
The distance of the hyoid bone to the vertebral column (The distance from the greater horn's posterior end to the vertebral column on the line drawn parallel to its long axis)	3.67±3.0	3.34±2.8	**0.456**	3.48±3.0	2.15±1.5	**0.000**	3.86±3.6	3.48±3.4	**0.515**	3.13±2.3	4.03±4.4	**0.230**
Angle of right and left greater horn (The angle between greater horn by connecting the lines passing through the midpoints of the anterior and posterior ends of the greater horn)	31.99±10.4	36.76±10.0	**0.003**	29.61±10.4	34.74±8.6	**0.000**	29.17±10.3	33.04±10.5	**0.027**	28.34±9.6	33.30±9.8	**0.028**
Vertebral level of the hyoid bone												
C2	11 (10.2)	17 (25.4)	0.002	8 (6.1)	21 (20.6)	0.000	3 (3.7)	7 (10.9)	0.203	0 (0.0)	3 (10.0)	**0.091**
C2-3	0 (0.0)	2 (3.0)		0 (0.0)	1 (1.0)		1 (1.2)	0 (0.0)		1 (1.9)	1 (3.3)	
C3	77 (71.3)	46 (68.7)		87 (65.9)	72 (70.6)		53 (64.6)	45 (70.3)		35 (67.3)	22 (73.3)	
C4	19 (17.6)	2 (3.0)		34 (25.8)	8 (7.8)		24 (29.3)	11 (17.2)		15 (28.8)	4 (13.3)	
C3-4	0 (0.0)	0 (0.0)		3 (2.3)	0 (0.0)		1 (1.2)	1 (1.6)		1 (1.9)	0 (0.0)	
C5	1 (0.9)	0 (0.0)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Fusion rank between the hyoid body and the greater horn												
Rank 0 (bilateral distance non-fusion)	31 (28.7)	24 (35.8)	0.381	3 (2.3)	3 (2.9)	0.604	0 (0.0)	1 (1.6)	0.613	0 (0.0)	0 (0.0)	0.688
Rank 1 (bilateral non-fusion)	50 (46.3)	33 (49.3)		74 (56.1)	62 (60.8)		34 (41.5)	23 (35.9)		14 (26.9)	8 (26.7)	
Rank 2 (partial fusion)	14 (13.0)	4 (6.0)		30 (22.7)	16 (15.7)		22 (26.8)	20 (31.2)		13 (25.0)	10 (33.3)	
Rank 3 (bilateral fusion)	13 (12.0)	6 (9.0)		25 (18.9)	21 (20.6)		26 (31.7)	20 (31.2)		25 (48.1)	12 (40.0)	
The Lingula-related morphological features of the hyoid bone												
Development (A, lingula developed at the central upper peripheral hyoid bone)	22 (20.4)	16 (23.9)	0.237	24 (18.2)	21 (20.6)	0.808	12 (14.6)	7 (10.9)	0.671	9 (17.3)	6 (20.0)	0.493
Scar (B, the scar of lingula was identified)	46 (42.6)	20 (29.9)		53 (40.2)	37 (36.3)		43 (52.4)	32 (50.0)		26 (50.0)	11 (36.7)	
Nothing (C, the lingula was not identified)	40 (37.0)	31 (46.3)		55 (41.7)	44 (43.1)		27 (32.9)	25 (39.1)		17 (32.7)	13 (43.3)	
The morphological appearance of the hyoid bone is												
A	63 (58.3)	40 (59.7)	0.406	94 (71.2)	67 (65.7)	0.167	58 (70.7)	48 (75.0)	0.838	35 (67.3)	25 (83.3)	0.217
B	39 (36.1)	26 (38.8)		31 (23.5)	33 (32.4)		19 (23.2)	13 (20.3)		10 (19.2)	4 (13.3)	
C	6 (5.6)	1 (1.5)		7 (5.3)	2 (2.0)		5 (6.1)	3 (4.7)		7 (13.5)	1 (3.3)	

prevalent type was type B (Scar) among males (44.9 %), ≥ 50 years patients, all age groups in males (except 30-49 years), and females aged (50-69) years. Type C (Nothing) was the most prevalent among females (43.2 %), < 50 years patients, all age groups in females (except 50-69 years), and males aged (30-49) years. Type A (Development) was the least in all comparison aspects.

Regarding the morphological appearance of hyoid bone, the differences were not significant. Type A was the most common according to sex (66.8 % in males vs 68.6 % females), age groups, and sex-specific age groups. Type C was the least common.

DISCUSSION

The hyoid bone has dual pharyngeal arch derivation; the lesser horns are derived from the second arch, the greater horns from the third arch, and the body arises from both arches. This development is associated with other structures, such as styloid process and laryngeal cartilages. In addition, ossification of the hyoid parts does not occur simultaneously; it starts at the long horns, followed by the body, and finally at the lesser horns (Hilali *et al*., 1997). Variations in shape and ossification can therefore result from changes in these embryological origins and ossification processes. For example, ossification can be extreme leading to complete ossification of the stylohyoid complex. Furthermore, such variations may be associated with different symptoms like otalgia, odynophagia, neck pain, and globus sensation in throat (Ekici *et al*., 2013).

Many methods have been used in measuring hyoid dimensions. Many researchers directly measured the hyoid parameters in cadavers after being processed (Fakhry *et al*., 2013). In the era of imaging, different modalities were used. Some authors prefer the cadaveric direct metric analysis as it is easy, cost effective, less expert demanding, does not need further image processing, and is not affected by probable imaging errors that might arise from interaction between radiation and tissue factors (Soltani *et al*., 2017). X-ray images were used previously in many morphometric studies, either radiographs of autopsies or those of live patients (Kollias & Krogstad, 1999; Shimizu *et al*., 2005). These methods are inexpensive with relatively lower radiation exposure (Ekici *et al*., 2013). Computed Tomography (CT) scans are superior in removing overlapping between different bony structures and soft tissues, as well as avoiding asymmetrical view due to improper position during the technique (Ito *et al*., 2012; Fakhry *et al*., 2013; Ekici *et al*., 2013). Recently, 3-D CT scans add the benefit of detecting relations between structures clearly and easily, as well as assessing fusion degrees of hyoid bone without removing it from the body (Loth *et al*. 2015; Ichijo *et al*., 2016).

In our study, all hyoid measurements were larger in males except for the angle between the greater horns. In addition, those parameters increase with age. These results are consistent with other studies. As the sternocleidomastoid muscles and other neck muscles are more developed in males, this might lead to narrower angle in this sex (Fakhry *et al*., 2013). Furthermore, the angle gets smaller with age, and this could result from the ossification of laryngeal cartilages leading to narrowing the thyroid angle, and hence affecting the hyoid bone shape by the attached thyrohyoid membrane (Dursun *et al*., 2021). Balseven-Odabasi *et al*. (2013) compared the hyoid dimensions of the Turkish population they studied to same measurements in preceding studies from Korea and United States. They concluded that differences indicate racial differences between various.

The hyoid size and shape can reflect or lead to some changes in the body. For example, the size is closely related to the middle part of laryngeal cavity (Papadopoulos *et al*., 1989). Controversies have been described in many reports about the relation of the hyoid bone morphometrics to the overall body weight, height, and body mass index (Fakhry *et al*., 2013; Rodríguez-Vázquez *et al*., 2015). For instance, the size is positively correlated with the weight and height of patients (Loth *et al*. 2015), but no correlation is found when the sex was controlled for (Rodríguez-Vázquez *et al*., 2015). After controlling BMI, the hyoid length and the distance between lesser horns were found to be independent predictors of sex in some series (Soltani *et al*., 2017). Unfortunately, these data were not available due to the retrospective nature of our study.

Although non-fusion between hyoid body and greater horns was present in more than half of the study sample, it was noticed that fusion increases with age in both sexes. Also, it was not different between males and females in each age-specific group. Our findings were consistent with some studies (Miller *et al*., 1998; Naimo *et al*., 2015) and different from others (Shimizu *et al*., 2005). Shimizu *et al* (2005) studied histologically the space between the body and greater horns, and found a fibrocartilaginous plate. The margin of the junction showed resorbed surfaces with osteoclast-like multinucleated giant cells. In fused hyoid bones, the junction lacked chondroid tissue, and the junction margin had rough surfaces without osteoclast-like cells. They suggested that this junction ossification is the only change in size that occurs to hyoid in adulthood. We think that the maximum ossification occurs in the sixth and seventh decades, and slows down afterwards. Furthermore, despite twenty one percent of our patients younger than 30 years started to have fusion (partial or complete bilateral), 26.8 % of patients who were 70 years old or more showed bilateral non-fusion. These findings suggest that this parameter cannot be used solely for predicting the age. However, distant bilateral non-fusion (Rank 0) was found in all patients younger than 10 years, and this rank was not seen in patients older than 60 years of age. In addition, the non-fused junction should not be mistaken as fractured hyoid in neck trauma cases. Moreover, it has been reported that fracture potential is greater in fused bones due to increased rigidity, and fractures commonly occur in the middle or posterior thirds of greater horns (Naimo *et al*., 2015). This is very important to be remembered by forensic medicine physicians when examining trauma cases or decomposed bodies (Balseven-Odabasi *et al*., 2013).

During swallowing, geniohyoid and mylohyoid muscles have the most potential to displace the hyoid bone anteriorly and superiorly; respectively (Pearson Jr. *et al*., 2011). Radiation therapy and surgery on the hyoid, as well as changes in the hyoid position relative to the mandible (e.g. during ageing in male) can affect the suprahyoid muscles function and can predispose to aspiration in some patients (Fakhry *et al*., 2013; Feng *et al*., 2014). Relative to cervical vertebrae, Bibby & Preston (1981) found a constant anteroposterior position of the hyoid with a mean of 31.76 mm (SD 2.9) with no sexual dimorphism. Like other studies, we found that the hyoid bone is mostly at C3 level in both sexes and age groups (Kollias & Krogstad, 1999). It was interesting that more inferior position (i.e at C4 level) was second in males at all ages and in females who are 50 years old or more. The inferior position of the hyoid has been often supposed to be a cause or a result of obstructive sleep apnea (Shepard Jr. *et al*., 1991; Fakhry *et al*., 2013).

Different shapes have been recorded in the literature. We described "U" shape, "V" shape, and "hoarseshoe" shape, and the first type was the most prevalent in our series. It has been suggested that the different shapes are continuous rather than discrete, and they arise from changes in synostosis ossification (Miller *et al*., 1998; Shimizu *et al*., 2005). The clinical significance of different shapes is unclear. Narrower hyoids are assumed to be associated with reduced pharyngeal volume, and possibly more severe airway obstruction. This can result from head and neck radiation therapy as well as neck dissection (Hilali *et al*., 1997; Fakhry *et al*., 2013). In addition, different shapes of the greater horns can reflect balance between the opposite biomechanical forces of tongue, cervical muscles, and ligaments (Rodríguez-Vázquez *et al*., 2015). Furthermore, repetitive microtrauma (e.g. during swallowing and excessive speaking) can lead to cartilage ossification (Ichijo *et al*., 2016). Moreover, "lingula" projection at the center of upper surface of hyoid body has been proposed to have remains of thyro-glossal duct (Parsons, 1909). It has many forms; "developed", "scar", and "Nothing". In this study it was "Nothing" in 39.7 %, which is relatively high compared to 9.3 % reported by Ito *et al*. (2012). This might represent population variations.

CONCLUSION

The hyoid bone is essential in swallowing, phonation, and respiration. Its dimensions are larger in males except for the angle between greater horns which is wider in females. The maximum growth of these dimensions is before age of 30 years. Fusion between hyoid body and greater horns was not seen in patients younger than 10 years. Otherwise, the hyoid features failed to predict age or sex in our sample. Furthermore, 3D-CT scan is an excellent tool that can be used in future studies to assess the functional anatomy of head and neck region.

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TARIFI, A. A.; SARHAN, S. Z.; AMER, M. A.; AL SAFARINI, A. D.; MUSTAFA, D. F.; ALTABAA, K. S.; OMARI, Y. B.; MUSTAFA, A. W.; SHATARAT, A. & BADRAN, D. Estudio morfométrico radiológico del hueso hioides mediante tomografía computarizada tridimensional (3D-CT). *Int. J. Morphol., 41(2)*:401-409, 2023.

RESUMEN: Se ha propuesto que las medidas del hueso hioides varían entre los diferentes sexos y grupos de edad. El objetivo del estudio fur estudiar la morfometría del hueso hioides en pacientes jordanos. Se analizaron tomografías computarizadas en 3D de 637 pacientes. Se midieron diez parámetros del hueso hioides, incluyendo la longitud anteroposterior, la longitud de los cuernos mayores (derecho e izquierdo), la altura de los cuernos mayores (derecho e izquierdo), el ancho del cuerpo hioides, la altura del cuerpo hioides, la distancia entre los puntos medios de los extremos posteriores de los cuernos mayores del hueso hioides, el ángulo entre los cuernos mayores derecho e izquierdo, y la distancia del hueso hioides a la columna vertebral. Además, se documentaron el nivel vertebral, el rango de fusión, la morfología de la língula del cuerpo hioides y la forma del hueso hioides. Todas las dimensiones del hioides fueron más largas en los hombres, pero el mayor ángulo de los cuernos fue más ancho en las mujeres. En pacientes menores de 30 años, los parámetros son los más pequeños con el ángulo más amplio. La distancia del hioides a la columna vertebral es mayor en el sexo masculino (30-49) años. No se observó fusión entre el cuerpo hioides y los cuernos mayores en pacientes menores de 10 años, pero se encontró fusión (unilateral o bilateral) en solo el 73,2 % de los pacientes ≥ 70 años. El hioides estaba mayormente al nivel de la vértebra C3 y en forma de “U”. La forma de la língula era mayoritariamente "Cicatriz" en los hombres (especialmente ≥ 50 años) y "Nada" en las mujeres (especialmente < 50 años). El máximo crecimiento de las dimensiones del hioides es antes de los 30 años. La fusión entre el cuerpo hioides y los cuernos mayores no se observó en pacientes menores de 10 años. No obstante, las características del hueso hioides no pudieron predecir la edad o el sexo en nuestra muestra. Además, la tomografía computarizada 3D es una herramienta excelente para evaluar la anatomía de la región de la cabeza y el cuello.

PALABRAS CLAVE: Hueso hioides; Morfometría; Edad; Sex.

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