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Original Article

Sex and side differences of three-dimensional Glenoid anthropometric parameters in a normal Turkish population

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Abstract

Aim: Due to anatomical differences, current baseplate designs may lead to incompatibilities in reverse shoulder arthroplasty in different populations. We hypothesized that glenoid anthropometric parameters in Turkish subjects would be different from that in other populations.

Materials and Methods: Three-dimensional morphology of 200 healthy Turkish shoulders (100 male and 100 females, 93 left and 107 right shoulders) was evaluated. Glenoid height, width, version, inclination, circumference, and surface area; glenoid depth, scapular neck length, and scapular neck angle were measured. Sex and side differences were assessed. The correlation between glenoid morphologic parameters and subject height was assessed. The height corresponding to a 25-mm glenoid width was predicted.

Results: There was a significant difference between male and female subjects regarding glenoid height, width, version, depth, circumference, surface area, and patient height ($p<0.05$). Also, there was a significant difference between right and left shoulders regarding glenoid height, glenoid width, glenoid version, glenoid surface area, superior depth, central depth, and inferior depth measurements ($p<0.05$). The glenoid height, width, retroversion, depth, circumference and surface area was well correlated with subject height. The estimated body height value to be obtained for a 25 mm glenoid width value was calculated as 164.4 cm.

Conclusion: Our results would be useful in patient selection, preoperative planning, determining the appropriate glenosphere sizes and glenoid component placement. The values of measurement parameters in this study may serve as reference values for normal Turkish population and may be helpful in the comparisons with other populations and osteoarthritic glenoids.

Keywords: Reverse shoulder arthroplasty; glenoid; anthropometry; computed tomography; glenosphere; height.

INTRODUCTION

Reverse shoulder arthroplasty has been used in the treatment of glenohumeral arthritis, glenoid bone loss, tumors, comminuted proximal humerus fractures, and revisions when the rotator cuff function is severely lost (1). Its popularity has been increasing worldwide. Medializing the center of rotation of the humeral head and lengthening the humerus are the main design characteristics that result in increased deltoid muscle tension and increased deltoid lever arm (2,3). These provide increased stability and abduction movement despite the absence of rotator cuff muscle forces. However, the medialized rotation center leads to impingement between the humeral polyethylene insert and the scapular neck (1).

Glenoid morphology is important in the application of the glenoid baseplate (4,5). Anatomical features of the glenoid may vary between different geographical regions and countries (6). Current baseplate designs are based on the morphology in the European and American populations, and they may not fit the Turkish population.

Glenosphere position and design was previously

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associated with impingement and scapular notching (7). An increased glenosphere size was shown to be effective in preventing impingement (8,9). The brands of prostheses available in Turkey (Aequalis Reversed II, Wright medical, TN, USA; Comprehensive reverse shoulder system, Zimmer Biomet, IN, USA; Humelock reversed, FX Solutions, Viriat, France and SMR System, Lima Corp, Udine, Italy) have a minimum glenoid size option of 25 mm. Even the smallest 25 mm glenosphere may be large in patients with small glenoids (6,10).

Difficulties in the application of glenoid baseplate in smaller sized glenoids have been reported (11). This size discrepancy may lead to stability problems and mechanical complications. Due to these complications, loosening of the glenoid component may occur (12). Also, proper glenoid baseplate insertion is important for screw placement as well as leaving adequate bone stock to provide bone–implant contact (13).

Glenoid width is commonly used as the limiting dimension in glenoid baseplate sizes, because, the glenoid height is always larger than the glenoid width (1). Moreover, excessive glenoid component retroversion, symmetric reaming in biconcave glenoid, or reaming without bone grafting may result in poor clinical and radiological outcomes (14). Therefore, preoperative evaluation of glenoid size, inclination, retroversion, and bone stock are important in the placement of glenoid component in the correct position and angle. To the best of our knowledge, there is no study evaluating the 3D glenoid morphology in Turkish subjects. The present study aimed to evaluate the morphology of normal glenoids in Turkish subjects using 3D CT.

obesity and the psychiatric conditions that obesity may cause should be taken into consideration (6,11,12).

Because of their versatility and ease of use, smartphones have become indispensable today. Taking into account the convenience they have brought in all areas of life, the most important problem in relation to the excessive use of smartphones is smartphone addiction (13,14). Researches on smartphone addiction, which is a behavioral addiction, are increasing (15-17). The relationship between multiple mental symptoms such as sleep quality, stress, anxiety, depression, personality, loneliness and smartphone addiction was investigated. (15,18,19). However, the number of studies investigating physical symptoms that may be associated with smartphone addiction is limited (16,20). And these studies mostly focus on upper extremity, neck and shoulder pain associated with excessive use of the smartphone (20-22).

There is no study in the literature investigating smartphone addiction and overweight, as far as we know. In this study, it is aimed to investigate the relationship between smartphone addiction and overweight with the assumption that smartphone may cause decreased physical activity and irregular nutrition. Another aim of the study was to determine whether smartphone use is a risk factor for obesity.

MATERIAL and METHODS

Between 2017 and 2018,767 patients were evaluated at our orthopedic emergency unit with shoulder pain following trauma. Of these, 351 patients had obtained a dedicated 2D CT scan of the shoulder. These scans were reviewed, and 34 patients were excluded for incomplete or inadequate study, glenoid deformity, glenoid bone defect, hardware artifact, and/or poor image quality. After exclusion, 200 of 317 patients (100 female and 100 male) were randomly selected and their 2D CT scans underwent 3D reconstruction using the method that was previously described by Bryce et al. (15). All measurements were obtained using GE Centricity Universal PACS viewer (GE Healthcare, Chicago, IL). Each patient had obtained a dedicated CT scan of the left or right shoulder girdle in the supine position with a GE Medical Systems Optima CT540 CT scanner (GE Healthcare, Chicago, IL) in increments of 0.2 mm. The in-plane pixel size was 0.4 mm to 0.7 mm. Our Institutional Review Board approved this study, and informed consent was not necessary as it was a retrospective study involving the CT images.

Measurement techniques

The maximum anteroposterior glenoid width and maximum superior-inferior glenoid height were measured manually. The surface contour of the entire articular surface was adjusted manually. The distance between the most superior to most inferior (glenoid height) and the most anterior to most posterior (glenoid width) points were measured. The surface contour, glenoid width, and glenoid height measurement techniques also allowed to measure the glenoid circumference and glenoid surface area (Fig. 1). The scapular plane was measured using the previously described 3D measurement technique (16). In this technique, three landmarks were selected, one on the glenoid center, one on the intersection between the scapular spine and the medial border, and one on the most inferior point of the scapular body. Then, the glenoid plane was measured according to the Ganapathi-Ianotti method (17). In this method, the superior pole of the glenoid and 2 points at the anterior and posterior third of the glenoid were marked. The glenoid version angle was determined as the angle between the scapular plane and the glenoid plane. The glenoid inclination was measured with the 3D technique described by Maurer et al. (18). The angle between the supraspinatus fossa and the glenoid face was defined as the inclination angle. The scapular neck angle (SNA) was measured using three points marked on the coronal plane: the most superior point of the glenoid (A), the most inferior point of the glenoid (B), and the point located 1 cm medial to the most inferior and lateral bone of the inferior glenoid rim (C) (9). The angle between the lines connecting points A and B and the lines connecting points B and C were calculated. Scapular neck length (SNL) was measured as the distance between the spino-glenoid notch and the lateral border of the infra-glenoid tubercle. The glenoid depth was measured from three points as the distance between the center of the glenoid fossa and the glenoid neck, the distance between the midpoint of the upper half of the glenoid fossa and glenoid neck, and the distance between the midpoint of the lower half of the glenoid fossa and glenoid neck. Measurements were performed by one radiologist and one orthopedic surgeon twice, 30 days apart.

Statistical analysis

The data were analyzed with IBM SPSS V23 (IBM corporation, Armonk, NY). Kolmogorov Smirnov test was used in the evaluation of the distribution of data. Independent samples t-test was used for comparison of gender and side parameters of the normal distribution. Mann Whitney U test was used for comparison of gender and side parameters of the non-normal distribution. Intra- and interobserver reliability for measurement parameters which were performed by one radiologist and one orthopedic surgeon to determine the validity of the measurements using the intraclass correlation coefficient. Spearman correlation analysis tested the relationship between subject height and measurement parameters. Linear regression analysis was used for causality between glenoid width and subject height. Analysis results were presented as mean ± standard deviation for normal distribution and as median (min-max) for normal non-dispersive data. The significance level was set at $p<0.05$.

RESULTS

The mean age of the subjects was 56.3 ± 12.5 (range, 18–66). The median height was 179 (range, 158–187) in male subjects and 163 (range, 154–178) in female subjects. Of the 200 shoulders, 93 were left and 107 were right shoulders. The mean glenoid height, width, retroversion, inclination, circumference, surface area, and depth, patient height, SNL and SNA are shown in Table 1.

There was a significant difference between right and left glenoids regarding mean glenoid height, width, retroversion, glenoid depth, and glenoid surface area values ($p=0.037$, $p=0.005$, $p=0.000$, $p=0.000$, and $p=0.003$, respectively) (Table 2). There was excellent intra- and interobserver agreement regarding all measurement parameters ($p=0.000$ and $p=0.000$, $r>0.91$ for all measurements).

When the relationship between the body height and measurement parameters was evaluated, a significant positive correlation was found between subject height and glenoid height, width, retroversion, depth, circumference, and surface area (Table 3).

When modeled as body height dependent variable and glenoid width independent variable, the model created as a result of linear regression analysis was found to be statistically significant ($p=0.000$). According to the "body height=103.849+2.422×Glenoid Width" equation, the estimated body height value to be obtained for a 25 mm glenoid width value was calculated as 164.4 cm.

Table 1. Comparison of male and female subjects' measurement parameters.

	Male	Female	Total	p
Glenoid height (mm) (mean± SD)	39.1 ± 2.5	34.5 ± 1.8	36.8 ± 3.2	0.000
Glenoid width (mm) (mean± SD)	27.7 ± 2.2	23.6 ± 1.6	25.6 ± 2.8	0.005
Glenoid version (°) (mean± SD)	-6.7 ± 3.4	-4.4± 3.7	-5.5 ± 3.7	0.004
Glenoid inclination (°) (mean± SD)	6.8 ± 4.6	7.5 ± 3.9	7.2 ± 4.2	0.561
Glenoid circumference (mm) (mean± SD)	127.9 ± 11.9	111.5 ± 6.6	119.7 ± 12.7	0.000
Glenoid surface area (mm2) [median (min-max)	959.4 (570.6 – 1316.3)	759.6 (580.6 – 910.2)	801.4 (570.6 – 1316.3)	0.000
Subject height (cm) [median (min-max)	179 (158 – 187)	163 (154 – 178)	170 (154 – 187)	0.000
Superior depth (cm) [median (min-max)	2.3 ± 0.5	2.0 ± 0.9	2.1 ± 0.7	0.001
Central depth (cm) (mean± SD)	3.4 ± 0.7	3.1 ± 0.8	3.3 ± 0.8	0.001
Inferior depth (cm) (mean± SD)	2.6 ± 0.7	2.3 ± 0.8	2.5 ± 0.7	0.001
Scapular neck length (mm) (mean± SD)	13.9 ± 3.5	11.5 ± 3.1	12.1 ± 3.4	0.000
Scapular neck angle (°) (mean± SD)	109.6 ± 12.3	109.2 ± 12.05	109.3 ± 12.1	0.052

Table 2. Comparative table of measurement parameters in right and left glenoids.

	Right (n=107)	Left (n=93)	Total (n=200)	p
Glenoid height (mm) (mean± SD)	37.5 ± 3.3	36.2 ± 2.9	36.8 ± 3.2	0.037
Glenoid width (mm) (mean± SD)	26.1 ± 2.3	24.6 ± 1.4	25.2 ± 2.9	0.005
Glenoid version (°) (mean± SD)	-6.96 ± 3.45	-4.13 ± 3.43	-5.49 ± 3.7	0.000
Glenoid inclination (°) (mean± SD)	4.44 ± 4.21	3.95 ± 4.24	4.19 ± 4.21	0.561
Glenoid circumference (mm) [median (min-max)]	119 (93 – 158)	114 (96 – 142)	117.5 (93 – 158)	0.050
Glenoid surface area (mm2) [median (min-max)	836.6 (570.6 – 1258.6)	772.3 (580.6 – 1316.3)	801.4 (570.6 – 1316.3)	0.003
Subject height (cm) [median (min-max)	174 (157 – 187)	169.5 (154 – 186)	170 (154 – 187)	0.052
Superior depth (cm) [median (min-max)]	2.3 (1.1 – 3.5)	2.0 (1.1 – 3.4)	2.1 (1.1 – 3.5)	0.000
Central depth (cm) (mean± SD)	3.36 ± 0.78	3.13 ± 0.7	3.23 ± 0.73	0.000
Inferior depth (cm) (mean± SD)	2.21 ± 0.72	2.62 ± 0.67	2.42 ± 0.69	0.000

Table 3. Correlation table between glenoid morphologic parameters and subject height r Spearman correlation coefficient

		Subject height
Glenoid height	r	0.867
	p	0.000
Glenoid width	r	0.746
	p	0.000
Glenoid retroversion	r	-0.286
	p	0.004
Glenoid inclination	r	-0.143
	p	0.416
Glenoid depth	r	0.787
	p	0.000
Glenoid circumference	r	0.766
	p	0.000
Glenoid surface area	r	0.824
	p	0.000

Table 4. Glenoid anthropometric parameters in different popularions

				Males mean	Females mean	Total mean
Mizuno et al. (6)	Japanese CT		Glenoid width (mm)	27.4	23.5	25.5
			Glenoid height (mm)	35.3	31.4	33.3
			Retroversion (°)	1.6	3.0	2.3
			Inclination (°)	10.4	12.8	11.6
	French CT		Glenoid width (mm)	28.7	24.7	26.7
			Glenoid height (mm)	37.3	33.5	35.4
			Retroversion (°)	6.2	5.9	6.0
			Inclination (°)	10.2	10.6	10.4
Matsumura et al. (21)	Japanese CT		Glenoid width (mm)	24.9	21.3	23.1
			Glenoid height (mm)	33.6	29.4	31.5
			Retroversion (°)	1.0	0	0
			Inclination (°)	-3.0	-1.0	-2.0
Churchill et al. (19)	American Cadaver	Black	Glenoid width (mm)	27.6	23.4	-
		White		28.1	23.8	-
		Black	Glenoid height (mm)	37.6	32.7	-
		White		37.4	32.5	-
		Black	Retroversion (°)	0.11	0.30	-
		White		2.87	2.16	-
		Black	Inclination (°)	3.6	4.2	-
		White		4.4	5.3	-
Ianotti et al. (20)	American Cadaver		Glenoid width (mm)	-	-	29
			Glenoid height (mm)	-	-	39
Merrill et al. (22)	American		Glenoid width (mm)	28.56	23.67	-
			Glenoid height (mm)	37.01	33.83	-
Merrill et al. (22)	American		Glenoid width (mm)	28.56	23.67	-
			Glenoid height (mm)	37.01	33.83	-
Tackett et al. (27)	American MRI		Retroversion (°)	5.95	4.95	-
Bicknell et al. (31)	Canadian CT		Glenoid width (mm)	24.5	20.6	-
			Glenoid height (mm)	44.2	36.7	-
McPherson et al. (32)	American Radiograph		Glenoid width (mm)	-	-	28.6
			Glenoid height (mm)	-	-	33.9
Yang et al. (5)	Chinese CT		Glenoid width (mm)	29.65	25.69	27.32
			Glenoid height (mm)	38.14	34.22	35.83
Mathews et al. (33)	Switzerland Cadaver and CT		Glenoid width (mm)	30.3	26.2	27.8
			Glenoid height (mm)	39.5	34.8	36.6
			Retroversion (°)	0	1	-
			Inclination (°)	15	12	-

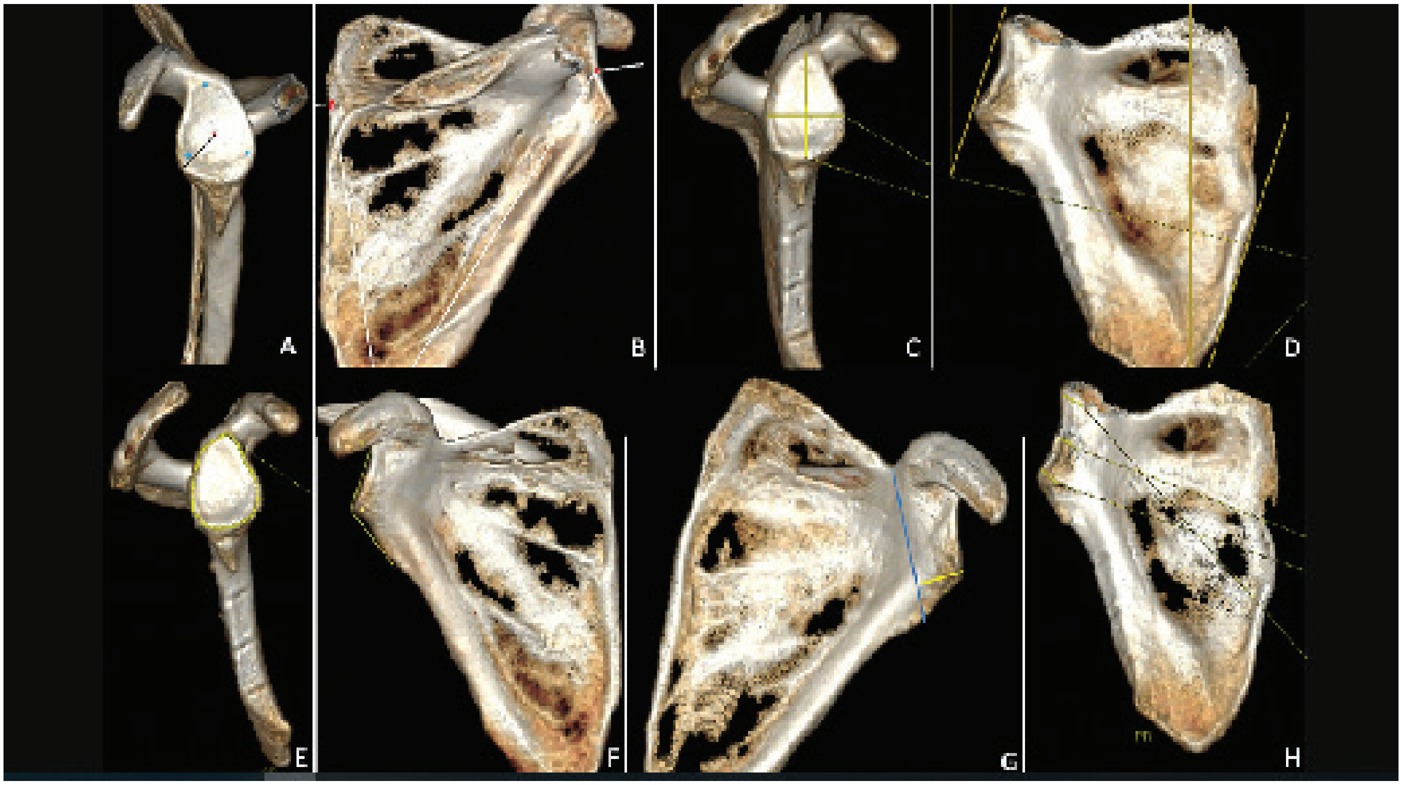

Figure 1. Examples of measurement techniques of glenoid plane and scapular plane (A and B), glenoid height and width (C), glenoid inclination (D), glenoid circumference (E), scapular neck angle (F), scapular neck length (G), and superior, central and inferior glenoid depth (H)

DISCUSSION

We found glenoid morphological differences between genders and sides. The morphological differences were found to be more prominent between female and male genders. The different glenoid morphologies may be associated with physical differences. Glenoid morphology in different populations was previously assessed (6,19-22). Variability in measurement parameters between genders, age groups, and geographical regions was reported in glenoid anthropometric parameters (Table 4). There has been no study evaluating normal Turkish glenoids. In this study, we analyzed comprehensive glenoid anthropometry using 3D-CT imaging. The normal Turkish glenoids have mean glenoid height of 36.8 mm, glenoid width of 25.6 mm, glenoid retroversion of 5.5°, glenoid inclination of 4.2°, glenoid surface area of 801.4 mm2, scapular neck length of 12.1 mm, and scapular neck angle of 109.3°. The mean superior, central and inferior depths of glenoid were 2.1 cm, 3.3 cm, and 2.5 cm, respectively. The mean height of Turkish men is reported to be 173.2 cm, and that of Turkish women 161.4 cm (Turkish Statistical Institute, Turkey 2016). The mean height of Japanese men is reported to be 171.9 cm and that of Japanese women is 158.4 cm (Ministry of Education, Culture, Sports, Science, and Technology–Japan 2013), Turkish people appear to be taller than the Japanese. Previously, Mizuno et al. (6) identified a significant positive correlation between body height and glenoid width in Japanese subjects. They found that the predicted height of the Japanese subjects that corresponded to a glenoid width of 25 mm was 161.3 cm. It was calculated as 164.4 cm in Turkish subjects. We found a significant positive correlation between subject height and glenoid height, width, retroversion, depth circumference, and surface area. We found a significant difference between the right and left sides regarding glenoid height, width, retroversion, surface area, and glenoid depth measurements. Greater measurement values were detected in dominant side measurements. However, Matsumura et al. (21) reported a strong correlation between dominant and nondominant shoulders regarding measurement parameters. Referring contralateral shoulder may cause wrong measurements, incompatible component placement and increased postoperative complication risk. According to our results, a 25 mm glenoid baseplate may be too large for some Turkish women, similar to what Mizuno et al. (6) and Matsumura et al. (21) reported for Japanese women. Our results would be helpful to improve clinical outcomes and glenoid component fitting in reverse shoulder arthroplasty for Turkish people. Glenoid height and width were relatively uniform in both male and female patients. Glenoid height was distributed between 29.1 mm to 44 mm. The values were clustering between 35 mm and 41 mm in 89% of men, and 30 mm and 38 mm in 96% of women. Glenoid width was distributed between 20.4 mm and 32.7 mm. The values were clustering between 25 mm and 32.7 mm in 92% of men, and 25 mm and 30.3 mm in 68% of women. These values may help to determine the glenosphere sizes fit for men and women. A 10° inferior tilt was recommended to prevent scapular notching at the time of glenoid baseplate placement (23). In our study, a mean of 7.2°superior tilt (6.8° in men and 7.5° in women) was found in Turkish subjects. It was smaller than that in both the Asian and European/American subjects (Table 4). Surgeons must be careful in their preoperative evaluation to avoid excessive inferior tilting intraoperatively. Glenoid bone stock should be taken into consideration while reaming and glenoid component placement. It affects stable component fitting, screw placement and overall glenoid component bone stability (13). We evaluated superior, central and inferior glenoid depth for the first time to determine glenoid bone stock in normal Turkish population. Glenoid circumference and the surface area were also measured. Our measurements could be used as reference values to compare normal glenoid anatomy and osteoarthritic morphological changes. In the literature, variability and errors were reported in the glenoid version measurement by 2D CT (24,25). Incorrect patient positioning and the height of the CT slice influence the measured values (6). We used a reproducible 3D measurement technique that was previously described by Ganapathi et al. (17). According to our results, a mean of 5.5° glenoid retroversion (6.7° in males and 4.4° in females) was found in the Turkish subjects. These values were between Asian and European/American populations (Table 4). It is recommended that excessive retroversion should be corrected at the time of glenoid baseplate placement (26). In our subjects, we found a higher glenoid retroversion angle than that in the Japanese subjects. The mean glenoid retroversion angle was found to be similar to western populations and higher than Japanese subjects (6,21,27). A wide variation was detected in our population regarding retroversion as other populations (Table 4). SNA and glenosphere position influence the development of impingement and scapular notching (9). It has been associated with polyethylene wear, inflammation, and osteolysis of the scapular neck (28). Glenoid component loosening and failure may develop if it progresses. The greatest adduction before impingement could be obtained in the presence of low SNA and inferior overhanging of the glenosphere (3). In patients with shorter SNL, lateralizing the glenosphere is recommended (29). In our study, the mean SNL was found to be 12.1 mm (range, 7.66–23.31 mm). Males had significantly larger SNL (13.90 mm) than females (11.5mm). The mean SNA was found to be 109.3° (range, 76.7–141.6°). In their study, Fortun et al. (30) reported a mean SNL of 10.6 mm and SNA of 106.7°. They showed significantly larger SNL in Caucasians than in African-Americans. A wide variation of SNA and SNL was reported in their population. Also, males and Caucasians tended larger SNL. Our results showed that the Turkish subjects had larger SNL and SNA than the African-Americans and Caucasians. No significant difference was found between males and females. SNL and SNA vary widely among the Turkish subjects as well. In addition to glenoid bone morphology, SNL and SNA should be taken into consideration in reverse shoulder arthroplasty preoperative planning to reduce postoperative complications such as scapular notching. There are several strengths and limitations of this study. The major strength was that our study population recruited from a wide range of working population including in the fields of light and heavy labor, competitive sports and with a wide range of age. Also, we had relatively high number of subjects and comprehensive measurement parameters. As limitations, firstly, we evaluated only the bony anatomy of glenoid. Adding soft tissues and cartilage may affect the anatomical measurements. Secondly, none of the subjects had arthritis. However, glenoid size and retroversion are increased in arthritic shoulders. Our results may be used as reference values to evaluate and compare the differences with arthritic glenoids. Thirdly, our patient cohort recruited from a high patient volume hospital in a metropol. Our results may not reflect the entire Turkish population. A multiregional comparative 3D-CT study would better elucidate the anatomical differences. Fourthly, the anatomical parameters were manually measured. An automated 3D measurement software was recently validated with lower measurement errors and intra- and interobserver discrepancies (21). We were not able to use that software because it was not available in our country. Finally, we did not perform measurements in cadaveric shoulders. As the measurements were done manually, a cadaveric CT and measuring the real sizes may be useful for adjusting the parameters.

CONCLUSION

Our results would be useful in the patient selection, preoperative planning, determining the appropriate glenosphere sizes and glenoid component placement. The values of measurement parameters in this study may serve as reference values for normal Turkish population and may helpful in the comparisons with other populations and osteoarthritic glenoids.

Competing interests: The authors declare that they have no competing interest.
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