

The Glenoid Fossa: Shape, Inclination and Version in Thais

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Abstract : A study of the glenoid fossa in Thais was carried out in ninety five normal shoulders in cadavers from the Department of Anatomy, Faculty of Medicine Siriraj Hospital. The mean age of the cadavers at the time of death was 69.8 years. In order to provide basic structural information of the glenoid orientation in adult Thais, the work was done by using a custom-made scapula holder which kept the scapula in position in which the reference line superimposed with the axis of the scapula. The angular measurement performed by using a goniometer placed contact on both rims of the glenoid and the center was superimposed with the reference line. Most of the scapulae, 85%, showed in upward inclination with the value of $+6.7^\circ \pm 3.4^\circ$ (mean $\pm$ SD) and 13% of the scapulae tilted downward with $-3.7^\circ \pm 1.9^\circ$. In a horizontal orientation, 81% of the scapulae faced backward (retroversion) with $-5.5^\circ \pm 3.0^\circ$ and 16% facing forward (anteroversion) with $+3.8^\circ \pm 1.6^\circ$. The similar figures were also found in the scapula from male and female cadavers; 8.5% of male scapulae had an upward inclination with $+6.3^\circ \pm 3.3^\circ$ and 13% a downward inclination with $-3.3^\circ \pm 1.9^\circ$ while 86% of the female scapulae tilted upward at $+7.1^\circ \pm 3.4^\circ$ and 12% at a downward inclination with $-3.7^\circ \pm 1.9^\circ$. Glenoid retroversion was found in 78% of male scapulae ($-4.9^\circ \pm 2.7^\circ$) and 86% in the female scapulae ($-6.1^\circ \pm 3.2^\circ$). The glenoid anteroversion was found in 20% of male scapulae ($+4^\circ \pm 1.5$) and 12% in female scapulae ($+3.5^\circ \pm 1.9^\circ$). Statistical analysis between genders and sides showed no significant difference, nor a correlation to the dominant arm.

Key words : scapula, glenoid fossa, inclination, version, Thais

เรื่องย่อ : แอ่งกลีนอย: รูปร่าง, ความลาดเอียงและการหันเหในคนไทย
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การศึกษาแอ่งกลีนอยในคนไทย จากหัวไหล่ปกติของอาจารย์ใหญ่ ที่ภาควิชากายวิภาคศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาลจำนวน 95 หัวไหล่ มีอายุเฉลี่ยขณะที่เสียชีวิตคือ 69.8 ปี เพื่อเป็นข้อมูลพื้นฐานทางกายวิภาคเกี่ยวกับรูปร่างลักษณะและการจัดตัวของแอ่งกลีนอยในผู้ใหญ่ไทย โดยการสร้างเครื่องมือเพื่อยึดกระดูกสะบักให้อยู่ในตำแหน่งที่ เส้นอ้างอิงเพื่อใช้วัดค่าของมุมอยู่ในแนวเดียวกับแนวแกนของกระดูกสะบัก การวัดมุมทำโดยใช้มาตรวัดมุม(ครึ่งวงกลมที่มีค่ามุมแสดงอยู่)วางบนขอบของกลีนอยและศูนย์กลางของมาตรทาบไปบนเส้นอ้างอิง

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พบว่ากระดูกสะบักส่วนใหญ่ 85% เอียงขึ้นบนทำมุม $+6.7^{\circ} \pm 3.4^{\circ}$ (ค่าเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐาน) และ 13% เอียงลงล่างด้วยมุม $-3.7^{\circ} \pm 1.9^{\circ}$ ส่วนการจัดตัวของกลีนอยในแนวระนาบพบว่า 81% แอ่งกลีนอยของกระดูกสะบักหันไปด้านหลังด้วยมุม $-5.5^{\circ} \pm 3.0^{\circ}$ และ 16% หันไปด้านหน้าด้วยมุม $+3.8^{\circ} \pm 1.6^{\circ}$ ซึ่งค่ามุมในทำนองเดียวกันนี้ก็พบในกระดูกที่จำแนกตามเพศ โดยในเพศชาย 85% แอ่งกลีนอยของกระดูกสะบักเอียงขึ้นบนด้วยมุม $+6.3^{\circ} \pm 3.3^{\circ}$ และ 13% เอียงลงล่างเป็นมุม $-3.3^{\circ} \pm 1.9^{\circ}$ ขณะที่ในเพศหญิง 86% เอียงขึ้นบนเป็นมุม $+7.1^{\circ} \pm 3.4^{\circ}$ และ 12% เอียงลงล่าง $-3.7^{\circ} \pm 1.9^{\circ}$ การหันไปด้านหลังของแอ่งกลีนอยพบ 78% ในเพศชาย ($-4.9^{\circ} \pm 2.7^{\circ}$) และ 86% ในเพศหญิง ($-6.1^{\circ} \pm 3.2^{\circ}$) ส่วนการหันไปด้านหน้าพบ 20% ในเพศชาย ($+4.0^{\circ} \pm 1.5^{\circ}$) และ 12% ในเพศหญิง ($+3.5^{\circ} \pm 1.9^{\circ}$) ผลจากการวิเคราะห์ทางสถิติไม่พบข้อแตกต่างอย่างมีนัยสำคัญระหว่างเพศและข้างของแขน ตลอดจนไม่มีความสัมพันธ์กับข้างที่ถนัด

INTRODUCTION

The shoulder or glenohumeral joint is formed by the articulation of the humeral head and glenoid fossa of the scapula. The glenohumeral joint exhibits the greatest range of motion, simultaneously sacrificing its stability for mobility. Recent works have tried to disclose the scientific ground on anatomic stabilizing structures of the glenohumeral joint which contribute to the interplay between the static and dynamic restraints of the joint¹⁻⁵. The static stabilizers of this joint are the articulating surfaces, articular capsule and glenohumeral ligaments. The dynamic stabilizers are surrounding muscles, especially the rotator cuff muscle. Turkel⁶ and his associates studied stabilizing mechanisms that prevented dislocation of the glenohumeral joint. They demonstrated that when the shoulder joint was in the neutral position (0°), the subscapularis muscle was the main stabilizer. When the shoulder joint abducted 45° the subscapularis, the middle glenohumeral ligament and part of the inferior glenohumeral ligament provided the major stability; at 90° abduction and external rotation, the shoulder joint dislocation was prevented by the inferior glenohumeral ligament. In term of the static stabilizer aspect, the bony articular surfaces of the glenohumeral joint are incongruent, but with the articular cartilage lining it is much more conforming. The glenoidal articular surface is pear shaped with its lower half being larger than the upper half. The glenoidal size is much smaller than that of the humeral

head. The humeral articular surface is approximately 3-4 times of the glenoid. During normal motion, the humeral head is actually in contact with the glenoid fossa, only 25%. The insufficient contact contributes to the inherent instability of the joint⁷. Orientation of the glenoid fossa relative to the body of the scapula has been implicated in the instability of the shoulder joint. The glenoid fossa does not always lie in a plane perpendicular to the axis of the body of the scapula. Most commonly, there is some degree of anterior or posterior angulation of the glenoid and also tilting upward and downward, known as version and inclination, respectively. Scientists from Ann Arbor, Michigan, reported that the inclination of the glenoid fossa was associated with the rotator cuff tears and affected superior humeral migration^{8,9}.

The version and inclination of the glenoid are basic structural facts which are hardly stated in standard anatomy textbooks. Knowledge on orientation of glenoid fossa can be a stepping stone for clinical research to disclose the mechanism of shoulder instability or rotator cuff pathology. The present work was carried out on cadavers used by second year medical students at the Department of Anatomy, Faculty of Medicine Siriraj Hospital. The aim of this study is to evaluate the version and inclination of the glenoid fossa in Thais, to determine the gender dimorphism of the glenoid orientation and the relationship of the tilting glenoid to the dominant arm.

MATERIALS AND METHODS

One hundred scapulae from adult Thai cadavers at the Department of Anatomy, Siriraj Hospital, were taken in order to investigate shape of the glenoid fossa as well as type and orientation of the glenoid fossa of the scapula. The scapulae with pathological change of the glenoid fossa were excluded. The ultimate number of scapula for studying the inclination and version of the glenoid cavity were 24 pairs and one single left scapula taken from a female cadaver, and 22 pairs and two left scapulae from a male cadaver. The average age was 69.82 years, ranging between 39-88 years. By means of telephone interviews with the relatives of all the cadavers, the dominant side was obtained and the absence of osteoarthritis or subluxation of their shoulder joints was confirmed. The scapulae were dissected in order to be freed from all the attached muscles and soft tissues excepted for labrum glenoidal. The general anatomic feature of the scapula was investigated and a photograph was taken.

The orientation or angular measurement of the glenoid fossa was done by using the custom-made scapula holder (Figure 1), modified from Churchill¹⁰. The device is composed of a basement platform with 2 side rods for holding the movable platform. In the middle of the platforms, small pin rods were fixed to hold the scapula in position. These two pin rods were in exactly the same line and perpendicular to the platform (Figure 1); the surfaces of the rods were marked with a straight line as a reference. By means of these two pins, the scapula was fixed and kept within its axis which traversed through the center of the glenoid fossa and medial edge of the spine of the scapula that joined with the medial border of the scapula. The scapula position was able to adjust according to the specific measurement by rotating around its transverse axis. The inclination measurement was made while the body of the scapula was placed in the same plane with the platform and its medial border was parallel (Figure 2). The version measurement was made when the scapula was placed perpendicular to the platform (Figure 3) while the medial border of the scapula was also kept parallel to the basement platform. Thereafter, the inclination and the version of the glenoid were read directly from the goniometer which was placed in contact with the glenoid margins; the center of the goniometer was superimposed on the reference line

or transverse axis of the scapula. The upward inclination was defined when the angle between the inferior glenoid rim and the reference line was greater than 90° and the downward inclination defined when the angle was less than 90°. By subtracting 90°, the readings were recorded and presented in plus and minus figures. Similarly, the anteversion was defined as the angle between the posterior glenoid rim and the reference line which was greater than 90° and retroversion was less than and subtracted 90°, the results were presented in plus and minus figures, respectively.

The angular measurements were statistically analyzed by using SPSS for Window version 11.5 (SPSS Inc. Chicago, IL). The tests for gender dimorphism and dominant side association with the orientation of the glenoid were carried out by Pearson's Chi-square test. The statistical significance was defined at $\alpha < 0.05$.

RESULTS

The glenoid cavity located on the lateral angle of the scapula is pear-shaped with variable indentation on the anterior rim which is called the glenoid notch. The dimension of the glenoid cavity has been reported by Piyawinijwong et al.¹¹ that the maximum superoinferior length of the glenoid fossa is 5.8 ± 0.35 cm. and 2.73 ± 0.31 cm. for the maximum anteroposterior length. The mean length measured from the most posterior rim to the glenoid notch is 2.6 ± 0.26 cm. The thickness of the neck of the scapula which abuts the glenoid fossa taken 1 and 2 cm. away from the glenoid rim was 1.91 ± 0.37 and 1.02 ± 0.27 cm., respectively.

The pear shape of the glenoid fossa is slightly variable and is categorized into 3 types as follows: type Ia is pear-shaped with a notch at the anterior rim, type Ib is pear-shaped without the glenoid notch and type II is an elongated ovoid shape. The percentage of glenoid types is presented in Table 1 which indicates that 26% were Ia type, 55% Ib and 19% type II. When looked at from the gender difference, the scapulae from male cadavers were 32% in Ia, 52% in Ib and 16% in type II while in female scapulae they were 20% in Ia, 58% in Ib and 22% in type II.

The mean values of inclination and version of glenoid are shown in Table 2. Eighty five percent of

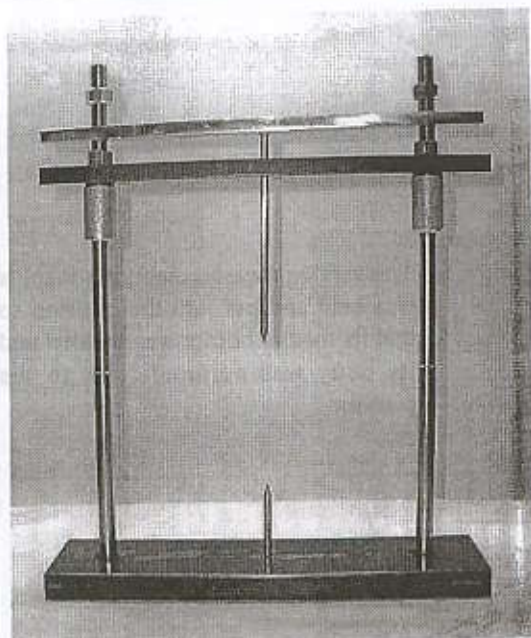


Figure 1. The scapula holder, a custom-made instrument, to hold the scapula between the 2 middle pins.

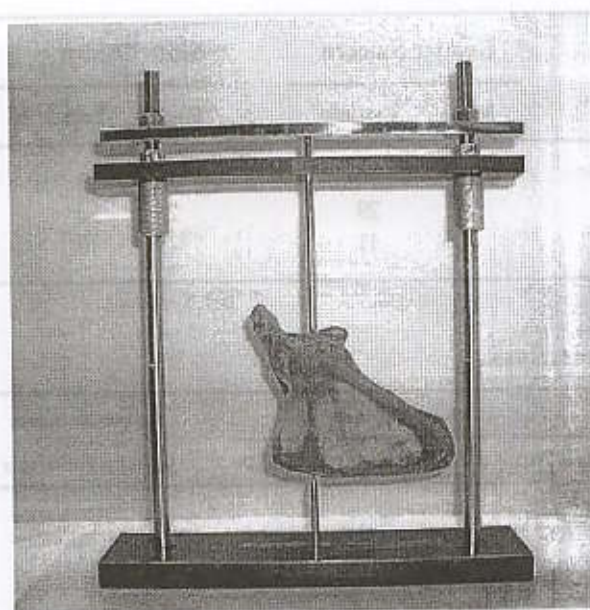


Figure 2. The inclination measurement; the scapula was held by the 2 middle pins and positioned within its axis which traversed the middle of the glenoid cavity to the junction between medial end of the spine of the scapula and medial border of the scapula.

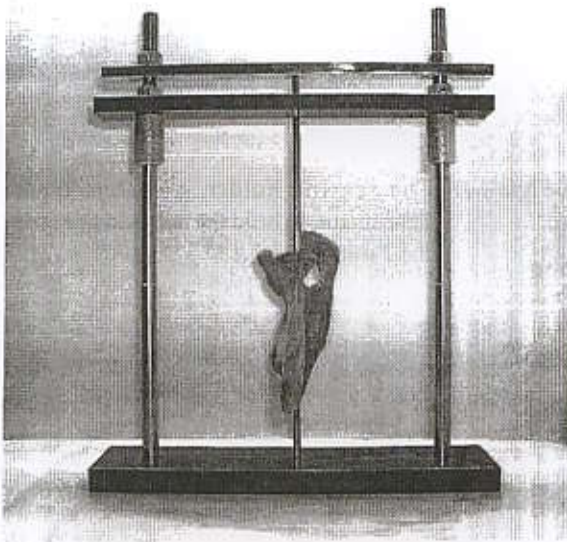


Figure 3. The version measurement; the scapula was held and put into the position so that its medial border was parallel and its body was perpendicular to the platform.

Table 1. Percentage of the glenoid type (%).

Type of Glenoid fossa	Total	Gender concern		Side concern	
		Male	Female	Right	Left
Pear shape with notch (Ia)	26	16	10	16	10
Pear shape without notch (Ib)	55	26	29	25	30
Elongated Ovoid (II)	19	8	11	9	10

Table 2. Angular measurement of the Glenoid fossa (in degrees).

Angular measurements	Total				Male				Female				Pearson Chi-Square test for sex difference
	%	min	max	Mean $\pm$ SD	%	min	max	Mean $\pm$ SD	%	min	max	Mean $\pm$ SD	
Inclination													
Upward	85	+1	+15	+6.7 $\pm$ 3.4	85	+1	+13	+6.3 $\pm$ 3.3	86	+2	+15	+7.1 $\pm$ 3.4	0.874
Downward	13	-1	-6	-3.7 $\pm$ 1.9	13	-1	-6	-3.3 $\pm$ 1.9	12	-1	-6	-3.7 $\pm$ 1.9	
Neutral	2	0	0	0	2	0	0	0	2	0	0	0	
Version													
Anteversion	16	+2	+7	+3.8 $\pm$ 1.6	20	+2	+7	+4.0 $\pm$ 1.5	12	+2	+7	+3.5 $\pm$ 1.9	0.326
Retroversion	81	-1	-13	-5.5 $\pm$ 3.0	78	-1	-10	-4.9 $\pm$ 2.7	84	-1	-13	-6.1 $\pm$ 3.2	
Neutral	3	0	0	0	2	0	0	0	4	0	0	0	

Table 3. The studies of glenoid version by various methodologies.

Authors	Sample and conditions (No.)	Mode of study	Mean/range of version (number/ % of specimen)
Churchill RS. et al. ¹⁸	Dry bone / Black men(50), White men(50), Black women(50), White women(22)	Anthropometry	-1.23° (BM -0.11°, WM -2.87°, BW -0.30°, WW -2.16°)
Gallino M. et al. ¹⁹	Egyptian scapulae (266)	Anthropometry	-2.° ± 2.9° (-7° to 13°)
Das SP. et al. ¹⁰	Dry scapula (50)	X-ray	-2° to -12° (30), +2° to +12° (20)
Saka AK. et al. ²⁰	Shoulder abducted 120° (50)	X-ray	-7.4° (73.5%), +2° to +10° (26.5%)
Cyprien JM. et al. ²¹	Shoulder (100)	X-ray	-8° ± 5.01° (Rt), -7.1° ± 4.6° (Lt)
Brewer BJ. et al. ²²	Nontraumatic instable shoulder (17)	X-ray	-9.8° (-3° to -15°)
Graichen H. et al. ²³	Atraumatic instability (17), traumatic instability (15)	X-ray	-9.3° (-4.5° to -17°) pre-op, -4.62° post-op, -1° control
Friedman RJ. et al. ²⁴	Osteoarthritis (10), Rheu.arthritis (8), gout (2)	CT scan	-11° ± 8° (+2° to -32°), control +2° ± 5° (+14° to -12°)
Bokor DJ. et al. ²⁵	Dry scapula various position	CT scan	-1° (+3° to -7.5°)
Couteau B. et al. ²⁶	A)-rotator cuff tear without bony change (4), B)-primary osteoarthritis (6), C)-rheumatoid arthritis (2)	CT scan 3D reconstruction	A) -17° (-12° to -22°), B) -27° (-4° to -48°), C) -31° (-25° to -31°)
Couteau B. et al. ²⁷	A)-rotator cuff tear without bony change (15), B)-primary osteoarthritis (13), C)-rheumatoid arthritis (4)	Quantitative CT Scan finite element	A)-8° (-2° to -17°), B)-16° (-0.2° to -50°), C) -15° (-6° to -22°)
Nyffeler RW. et al. ²⁸	A) Instability shoulder (25), B) post total arthroplasty (25)	CT scan	A)-3° (-7° to -16°), B)+2° (+16° to -23°)
Inui H. et al. ²⁹	Normal subject (40: male 20, female 20)	3D MRI sectioning	twist sequentially superior to inferior, +3.3° ± 4.1°, +1.4° ± 3.8°, -0.6° ± 1.9°, -1.4° ± 3.3°, -6.2° ± 3.3°
Tétreault P. et al. ³⁰	A) ant cuff involve ant tendon(29), B) isolated tear of supraspinatus(22), C) post cuff and tendonitis(24), D) global cuff tear(21)	MRI	Mean -9° ± 5°; A)-5° ± 4°, B)-3° ± 4°, C)+3° ± 3°, D) 0° ± 4°

the total scapulae tilted upward, 13% had a downward inclination and the remaining 2% were in a neutral position. The mean degree of upward tilting was $+6.7^\circ \pm 3.4^\circ$ (mean ± standard deviation) ranging between $+1^\circ$ to $+15^\circ$ while the downward inclination was $-3.7^\circ \pm 1.9^\circ$ ranging from -1° to -6° . The upward inclination (85 and 86% in males and females, respectively) was found most in both genders (Figure 4), while the downward inclination (13 and 12% in males and females, respectively) was less. Similarly, the side of the glenoid cavity (Figure 5), also showed an upward inclination on both sides (85 and 86%, right and left sides, respectively). There was no significant difference between genders and sides nor an association with the dominant side which mostly indicates right handed people.

The majority of the scapulae were presented with the glenoid tilted backwards (81%), 16% tilted forward and 3% in a neutral position. The mean value of the retroversion was $-5.5^\circ \pm 3^\circ$ ranging between -1° to -13° and of the glenoid anteversion $+3.8^\circ \pm 1.6^\circ$ ranging from $+2^\circ$ to $+7^\circ$ (Table 2). Most of the glenoids from female cadavers were retroversion (86%), slightly larger than those from males (78%), and anteversion

in female was 10% lesser than in males (28%) (Figure 6). On the side aspect, 87% of retroversion was found on the right side and 78% on the left while the anteversion of the right scapula was 9% and of the left 20% (Figure 7). However, there was no significant difference of version in genders and sides nor an association to the dominant arm.

DISCUSSION

Most of the scapulae exhibited the pear-shaped glenoid fossa without the glenoid notch in both genders. The orientation of the glenoid fossa in this work generally corresponded with the previous studies that a majority of the glenoid tilted upwards and faced backwards. Similarly, there was not a significant different between genders and sides of the scapulae. The shape and orientation of the glenoid played a crucial role in static stability of the glenohumeral joint. The excessive upward inclination increased the risk for superior humeral translation and also involved rotator cuff pathology^{8,9}. The stability of the glenohumeral joint depends on the net humeral joint reaction force acting directly within the effective

Glenoid inclination in male and female

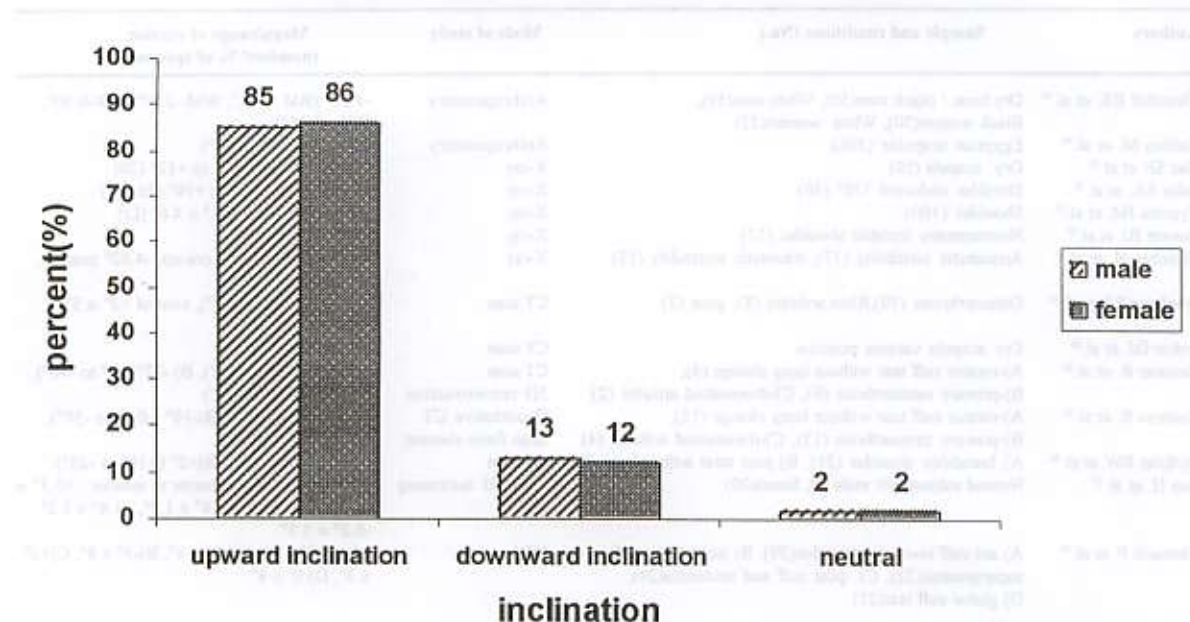


Figure 4. Histogram showing percentage of the glenoid inclination in males and females.

Glenoid inclination in the right and the left sides

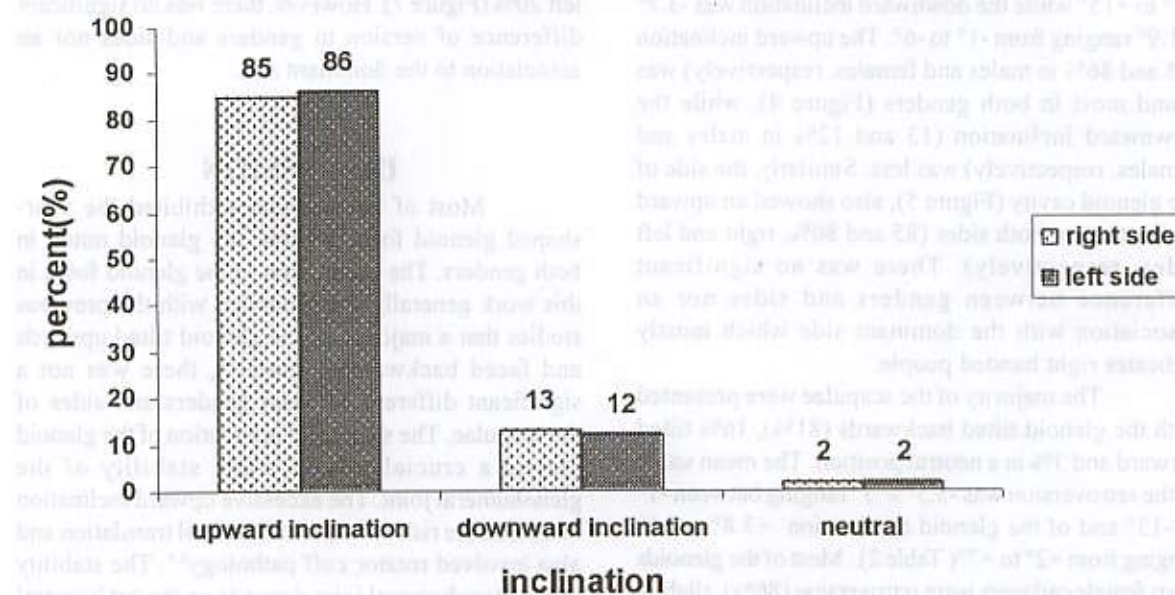


Figure 5. Histogram showing percentage of the glenoid inclination in the right and the left sides.

Glenoid version in male and female

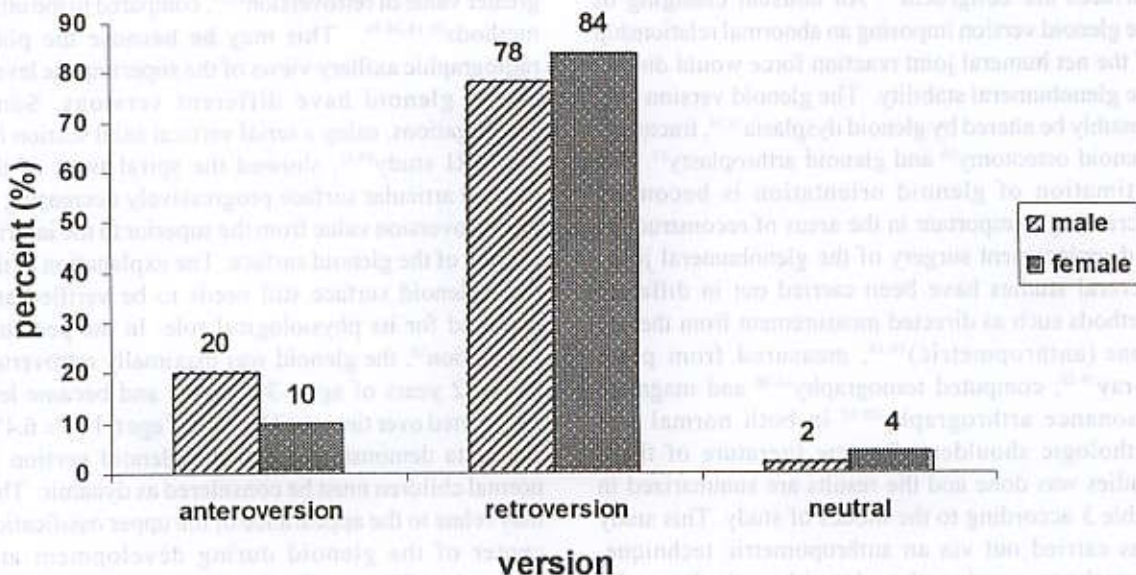


Figure 6. Histogram showing percentage of the glenoid version in males and females.

Glenoid version in the right and left sides

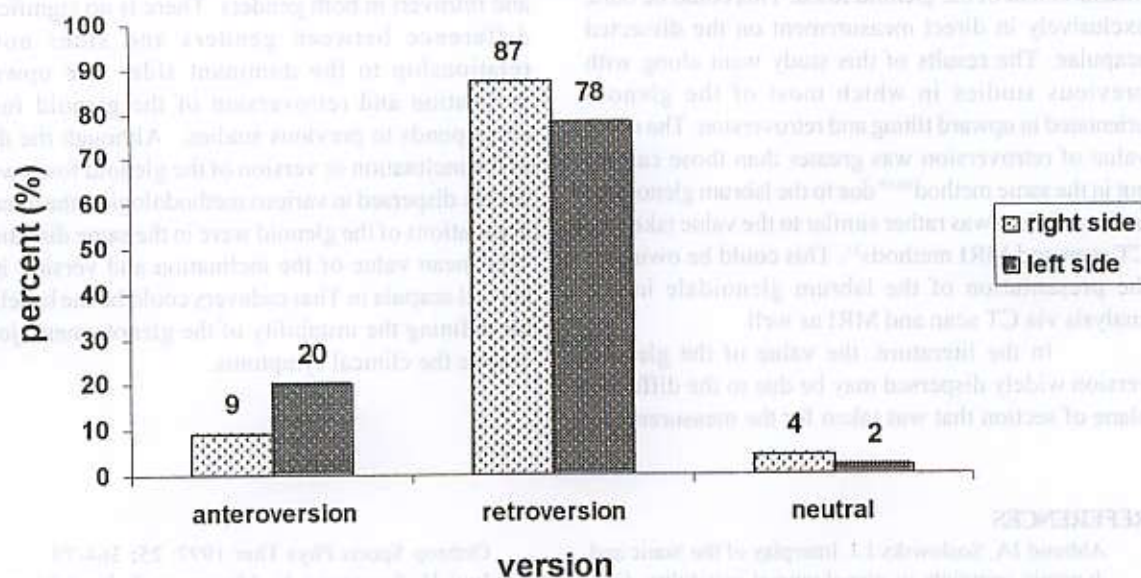


Figure 7. Histogram showing percentage of the glenoid version in the right and the left sides.

glenoid arc. The humeral head remains centered in the glenoid fossa if the glenoid and humeral joint surfaces are congruent¹². An unusual changing of the glenoid version imposing an abnormal relationship of the net humeral joint reaction force would disturb the glenohumeral stability. The glenoid version may possibly be altered by glenoid dysplasia^{13,14}, fracture¹⁵, glenoid osteotomy¹⁶ and glenoid arthroplasty¹⁷. The estimation of glenoid orientation is becoming increasingly important in the areas of reconstructive and replacement surgery of the glenohumeral joint. Several studies have been carried out in different methods such as directed measurement from the dry bone (anthropometric)^{10,18}, measured from plain X-ray^{19,23}, computed tomography^{24,28} and magnetic resonance arthrography^{29,30} in both normal and pathologic shoulders. Review literature of these studies was done and the results are summarized in Table 3 according to the modes of study. This study was carried out via an anthropometric technique, directly measuring the glenoid angle from the scapulae taken from the cadaver which claimed to provide precise and reproducible data³¹. However, it was difficult to perform in vivo which was essential for clinical studies. The established accuracy of the scapula axis was essential for precise angular measurement of the glenoid fossa. This could be done exclusively in direct measurement on the dissected scapulae. The results of this study went along with previous studies in which most of the glenoid orientated in upward tilting and retroversion. The mean value of retroversion was greater than those carried out in the same method^{10,19} due to the labrum glenoidale in situ, while it was rather similar to the value taken by CT scan and MRI methods³¹. This could be owing to the presentation of the labrum glenoidale in the analysis via CT scan and MRI as well.

In the literature, the value of the glenoid version widely dispersed may be due to the different plane of section that was taken for the measurement.

The angular measurement taken from the plain radiographs of normal shoulders tended to yield a greater value of retroversion^{20,21}, compared to the other methods^{10,18,24,30}. This may be because the plain radiographic axillary views of the superimpose levels of the glenoid have different versions. Some investigations, using a serial vertical axial section for 3D MRI study^{29,31}, showed the spiral twist of the glenoid articular surface progressively decreasing in the retroversion value from the superior to the inferior portion of the glenoid surface. The explanation of the twist glenoid surface still needs to be verified and explored for its physiological role. In the pediatric population³², the glenoid was maximally retroverted before 2 years of age ($-3^\circ \pm 6.5^\circ$) and became less retroverted over time until 8 years of age ($-1.7^\circ \pm 6.4^\circ$). The data demonstrated that the glenoid version in normal children must be considered as dynamic. This may relate to the appearance of the upper ossification center of the glenoid during development and maturation. This ossification center is concealed by the end of the first decade.

CONCLUSION

Normal scapulae in Thais mostly tilt upwards and retrovert in both genders. There is no significant difference between genders and sides nor a relationship to the dominant side. The upward inclination and retroversion of the glenoid fossa corresponds to previous studies. Although the data of the inclination or version of the glenoid fossa were widely dispersed in various methodologies, the overall orientations of the glenoid were in the same direction. This mean value of the inclination and version in a normal scapula in Thai cadavers could be the baseline for defining the instability of the glenohumeral joint despite the clinical symptoms.

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