3

MEASUREMENT of RANGE of MOTION of the SHOULDER

Nancy Berryman Reese

The *shoulder joint complex* is composed of three synovial joints (glenohumeral, acromioclavicular, and sternoclavicular) along with the articulation between the ventral surface of the scapula and the dorsal thorax (herein referred to as the scapulothoracic articulation)[1] (Fig. 3.1). Although other structures, such as the "subacromial joint,"[2] occasionally are included as part of the shoulder joint complex, a more conservative, four-articulation description of the complex is used in this text.[1] In the following sections, anatomy and motion at each articulation will be described separately before the combined motions of the shoulder complex are discussed.

GLENOHUMERAL JOINT

ANATOMY

The glenohumeral joint is classified as a ball-and-socket joint that is formed by the articulation of the rounded humeral head with the anterolaterally facing glenoid fossa of the scapula[3] (see Fig. 3.1). Because the glenoid fossa is shallow and provides only a small articular surface for the head of the humerus, the glenohumeral joint possesses some inherent instability. Reinforcement of the joint is provided by ligamentous (Fig. 3.2) and musculotendinous structures as well as by the fibrocartilaginous glenoid labrum, which is attached to the margin of the glenoid fossa, effectively increasing its depth and adding stability to the joint.[4] Musculotendinous reinforcement of the glenohumeral joint is supplied by the tendons of rotator cuff muscles (subscapularis, supraspinatus, infraspinatus, and teres major) as they cross the anterior, superior, and posterior aspects of the joint capsule, respectively.[5,6] The glenohumeral ligaments consist of superior, middle, and inferior bands, although the distinctness of these ligaments has been questioned.[7] The collective role of the glenohumeral ligaments is to strengthen the anterior and inferior walls of the joint capsule and to provide some limitation to lateral rotation of the shoulder, particularly between 0 and 90 degrees of arm elevation.[8–10] Additional reinforcement of the superior aspect of the glenohumeral joint is provided by the coracohumeral ligament, which runs from the coracoid process of the scapula to the greater tuberosity of the humerus.[9]

OSTEOKINEMATICS

The relative instability of the glenohumeral joint allows large freedom of movement, permitting placement of the upper extremity in a wide variety of positions for function. The joint has 3 degrees of freedom of movement, allowing the motions of flexion/extension, abduction/adduction, and medial/lateral rotation.

Motion at the glenohumeral joint is limited primarily by muscular and capsuloligamentous structures. Elevation (flexion or abduction) is limited by tension in the inferior glenohumeral ligament and the inferior joint capsule.[10] Extension is limited by the superior and middle glenohumeral ligaments.[2] Glenohumeral rotation is limited by ligamentous structures and by tension in muscles of the rotator cuff. Lateral rotation is limited by tension in the subscapularis muscle, in the anteroinferior joint capsule, and in the coracohumeral, superior and middle glenohumeral, and anterior band of the inferior glenohumeral ligaments.[9,11–13] Medial rotation at the glenohumeral joint is limited by tension in the infraspinatus and teres minor muscles, in the posterior joint capsule, and in the posterior band of the inferior glenohumeral ligament.[11–13]

ARTHROKINEMATICS

At the glenohumeral joint, motion is produced by gliding, rolling, and spinning of the convex head of the humerus against the shallow, concave surface of the glenoid fossa of the scapula. During movement at this joint, the head of the humerus rolls in the same direction in which the distal end of the humerus is moving and glides in the opposite direction. For example, as one moves from 0–90 degrees of flexion, the humeral head rolls superiorly and glides inferiorly. In addition, the head of the humerus spins within the glenoid fossa, particularly during rotational motion of the joint.[14]

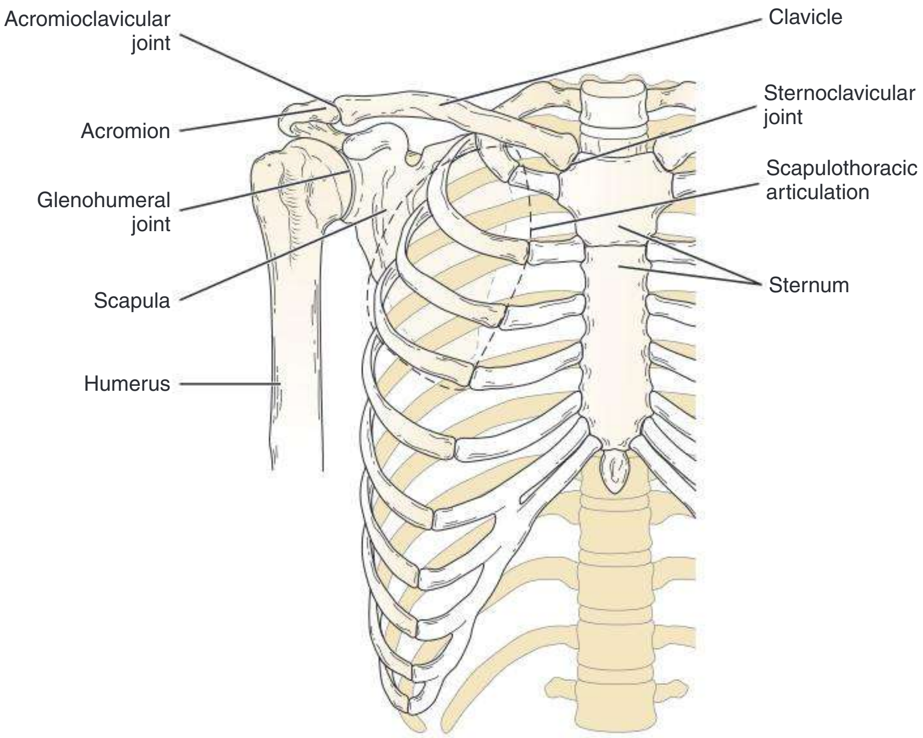

Fig. 3.1 Joints of the shoulder complex.

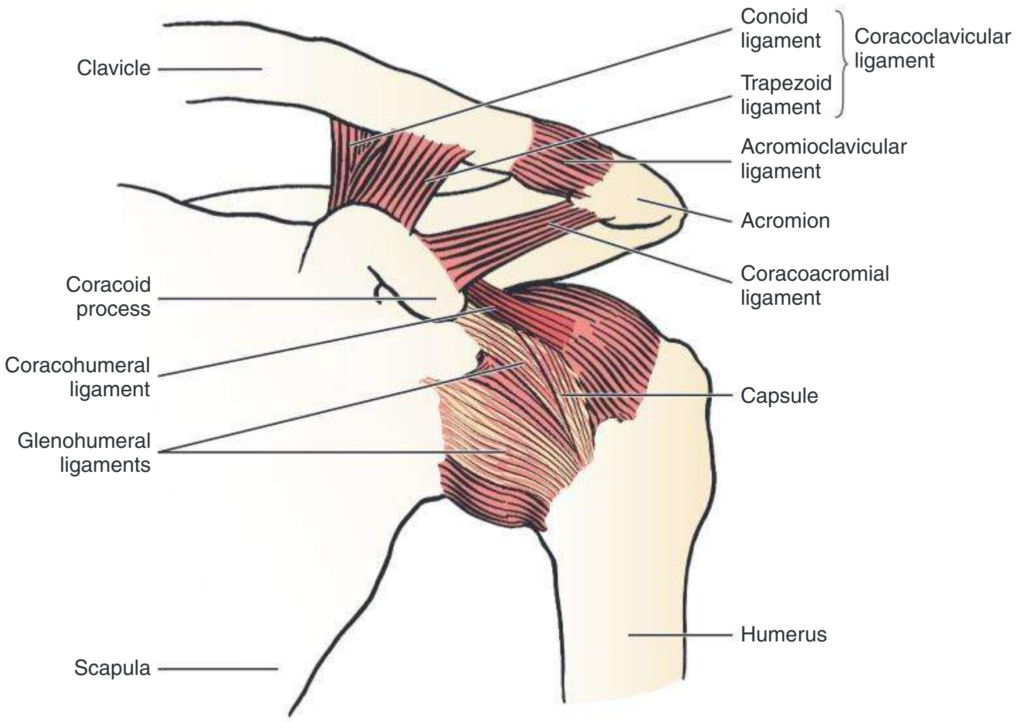

Fig. 3.2 Ligamentous reinforcement of the glenohumeral and acromioclavicular joints.

STERNOCLAVICULAR JOINT

ANATOMY

The sternoclavicular joint, the only synovial articulation between the upper limb and the axial skeleton, is formed by the articulation of the sternal end of the clavicle with the manubrium of the sternum and cartilage of the first rib[3] (Fig. 3.3). No actual bony contact occurs between the clavicle and the sternum. Instead, a thick fibrocartilaginous disc is interposed between the articular surfaces of the two bones, increasing the congruency between them and separating the joint into two completely separate parts.[1,6] Four ligaments provide reinforcement for and limit motion at the sternoclavicular joint: the anterior and posterior sternoclavicular ligaments, the costoclavicular ligament, and the interclavicular ligaments. The anterior and posterior sternoclavicular ligaments are attached laterally to the sternal end of the clavicle and medially to the manubrium of the sternum, and they reinforce the anterior and posterior aspects of the joint capsule, respectively. Further reinforcement of the joint is provided by the costoclavicular ligament, which runs from the inferior aspect of the clavicle to the superior aspect of the first rib. The interclavicular ligament attaches to the sternal end of each clavicle and reinforces the superior aspect of the sternoclavicular joint.[1,3,6]

OSTEOKINEMATICS

Three degrees of freedom of movement are allowed by the structure of the sternoclavicular joint. Because the distal end of the clavicle is attached to the acromion process of the scapula (acromioclavicular joint), all movements of the clavicle are accompanied by movements of the scapula. Motions at the sternoclavicular joint consist of the following:

Elevation/Depression—Defined as superior and inferior movement of the distal end of the clavicle, respectively.

Protraction/Retraction—Anterior/posterior movement of the distal end of the clavicle.

Rotation—A spinning motion of the clavicle around its longitudinal axis.[15,16]

Motions of the sternoclavicular joint are limited by the ligaments that surround the joint and the fibrocartilaginous joint within. The anterior and posterior sternoclavicular ligaments limit protraction and retraction of the clavicle. Elevation of the clavicle is checked by tension in the costoclavicular ligament, and depression is limited by the interclavicular ligament and the articular disc.[6,14]

ARTHROKINEMATICS

During the motions of clavicular elevation and depression, movement occurs between the clavicle and the articular disc. Because the sternal end of the clavicle is convex in a cephalocaudal direction, elevation of the acromial end of the clavicle causes the sternal end to glide inferiorly, and depression causes the sternal end to glide superiorly. Clavicular protraction and retraction occur as motions between the articular disc and the sternum. In this instance, the articular surface on the clavicle is concave, causing the medial and lateral ends of the clavicle to move in the same direction. Thus protraction is accompanied by an anterior glide of the sternal end of the clavicle, while the sternal end glides posteriorly during retraction. Rotary movements of the clavicle result in a spin of the sternal end of the clavicle. Because of the S-shape of the clavicle, posterior rotation at the sternoclavicular joint results in elevation of the lateral end of the clavicle.[1,14,17]

ACROMIOCLAVICULAR JOINT

ANATOMY

The acromioclavicular (AC) joint is classified as a plane synovial joint and is formed by the articulation of the acromial end of the clavicle with the medial border of the

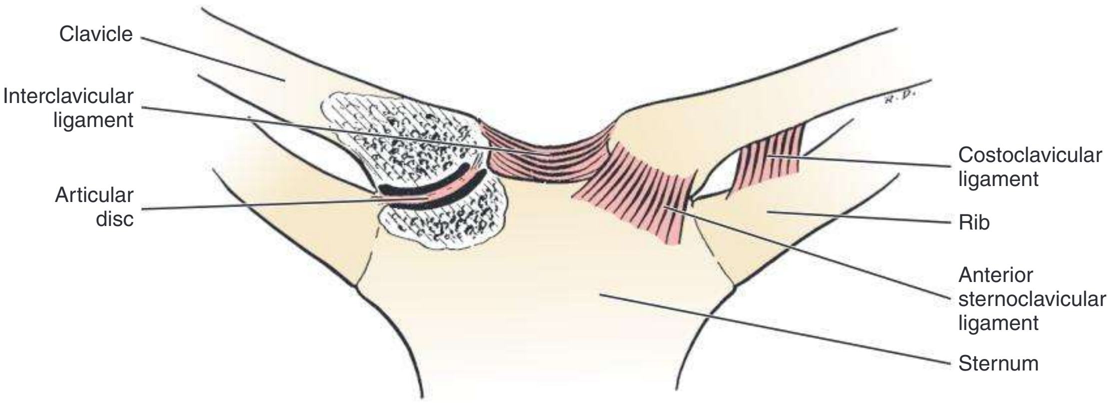

Fig. 3.3 Bony and ligamentous anatomy of the sternoclavicular joint.

acromion process of the scapula (see Fig. 3.2). Both articular surfaces are covered with fibrocartilage, and the joint line formed by the two bones slopes inferiorly and medially, causing the clavicle to tend to override the acromion. This tendency is prevented to a large extent by the strong coracoclavicular ligament that runs from a broad area of origin on the inferior aspect of the clavicle to a tapered insertion on the coracoid process of the scapula.[18,19] The more horizontally oriented fibers of the trapezoid component of this ligament resist medial displacement of the scapula.[20] The other component of the coracoclavicular ligament, the conoid ligament, has fibers that are oriented more vertically. Additional reinforcement of the AC joint is supplied by the AC ligament and by fibers of the deltoid and trapezius muscles, all of which span and reinforce the superior aspect of the joint.[13,19,20]

OSTEOKINEMATICS

The AC joint has been described as having 3 degrees of freedom. Although considerable variation has been noted in the nomenclature used to describe motions that occur at the AC joint,[1,14,16] these motions include rotation around an anterior–posterior axis, winging around a vertical axis, and tilting around a medial-lateral axis.[16] AC motions of rotation, winging, and tilting occur during scapular motions of rotation, abduction/adduction, and elevation/depression, respectively.

ARTHROKINEMATICS

The articular surfaces at the AC joint consist of a slightly convex to relatively flat facet of the clavicle and a slightly convex to relatively flat acromial surface. Because of the irregularity of the joint surfaces and the complexity of movement produced at this joint, arthrokinematics of the AC joint are not well described in the literature.[14,17]

SCAPULOTHORACIC ARTICULATION

ANATOMY

Although the scapula moves on the thorax during motions of the shoulder complex, the articulation between the scapula and the thorax is not a true joint in any sense of the term. However, motion between the scapula and the thorax contributes greatly to full mobility of the shoulder complex. Articulation here occurs between the concave costal surface of the scapula and the convex surface of the posterior thorax (Fig. 3.4).

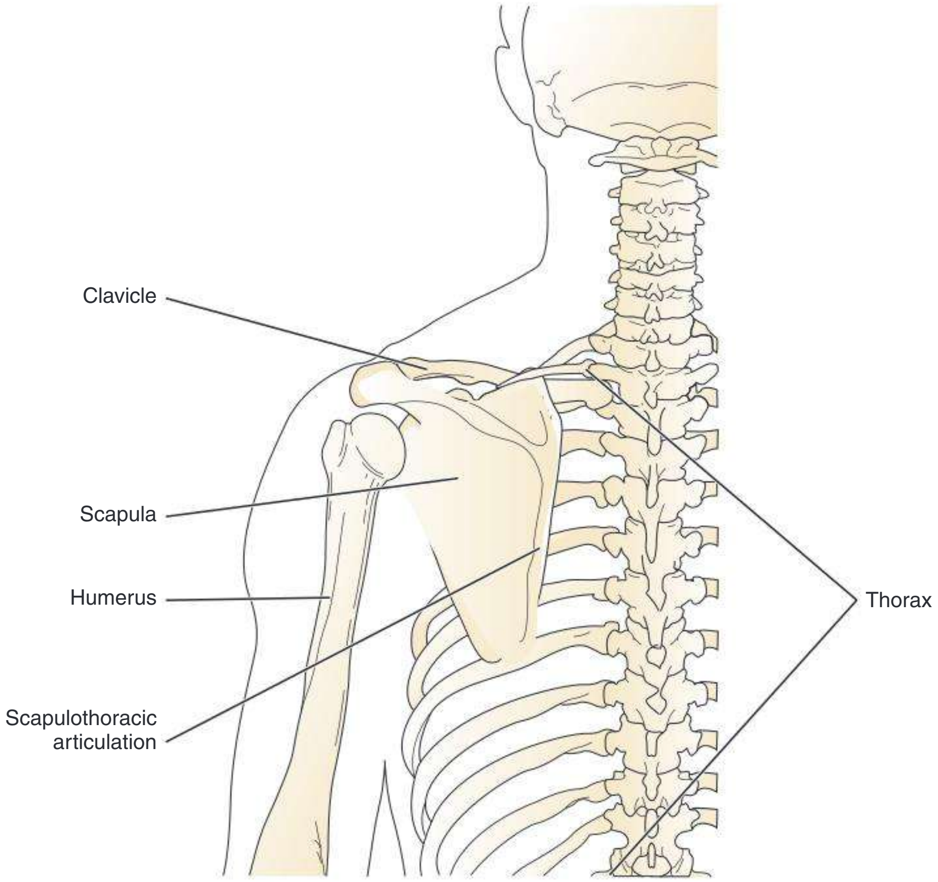

Fig. 3.4 Scapulothoracic articulation (posterior view).

OSTEOKINEMATICS

Movements of the scapula on the thorax result from combined motions of the sternoclavicular and AC joints and are essential for full range of motion (ROM) of the shoulder complex. Motions available at the scapulothoracic articulation include scapular elevation and depression, abduction and adduction, and upward and downward rotation.[14]

ARTHROKINEMATICS

Because the scapular surface is concave and moves on a convex thorax, the scapula moves as a unit, gliding along the thoracic surface as it follows motions of the clavicle.[14]

SHOULDER COMPLEX

Motions of the shoulder joint complex include flexion, extension, abduction, adduction, medial rotation, and lateral rotation. These movements of the shoulder joint contain component motions that occur at all four articulations composing the shoulder complex. For example, elevation of the arm in the frontal plane (shoulder abduction) or the sagittal plane (shoulder flexion) is accomplished by motions that occur at the glenohumeral joint (glenohumeral flexion or abduction), at the sternoclavicular joint (clavicular elevation), at the AC joint (clavicular rotation), and at the scapulothoracic articulation (scapular abduction, elevation, and upward rotation). Elevation of the arm is produced by a combination of humeral and scapular motion, which has been described as occurring in varying ratios of glenohumeral to scapulothoracic motion. Although it is widely accepted that the relative contributions of glenohumeral and scapulothoracic movements vary throughout the range of arm elevation, the overall ratios of glenohumeral to scapulothoracic motion have been reported from as high as 2:1[21] to as low as 1.1:1,[22] with other ratios reported between those values.[23–25] There also is evidence that the ratio of scapulothoracic to glenohumeral motion decreases as the motion progresses from the coronal plane (abduction) to the sagittal plane (flexion).[26] The motion of the scapula is a result of motion that occurs at the AC and sternoclavicular joints, whereas humeral motion is produced at the glenohumeral joint. Because isolated glenohumeral motion does not occur during normal elevation of the arm past the first 30 degrees or so,[21,27] no attempt is made in this text to measure isolated glenohumeral flexion or abduction. Rather, flexion and abduction are measured as shoulder complex motions, allowing full excursion at all involved joints.

LIMITATIONS OF MOTION: SHOULDER JOINT

Because motions involving elevation of the arm are combined motions involving movement at the AC, glenohumeral, and sternoclavicular joints, as well as at the scapulothoracic articulation, shoulder flexion and abduction are limited by anatomical structures located at multiple joints. For example, elevation of the arm may be limited by tension in the costoclavicular ligament,[3] which limits clavicular elevation (necessary for complete elevation of the arm). The same motion may be limited by tension in the inferior glenohumeral ligament, thereby restricting motion at the glenohumeral joint. For a complete description of structures that limit joint motion, refer to the descriptions of osteokinematics for each joint of the shoulder complex. Information regarding normal ranges of motion for all motions of the shoulder is found in Appendix B.

END-FEEL

All motions of the shoulder joint complex are restricted by capsuloligamentous or musculotendinous structures. Thus the normal end-feel for all motions of the normal shoulder joint complex is firm.

CAPSULAR PATTERN

Decreased shoulder ROM should be assessed to determine whether the limitation occurs in a capsular pattern. Capsular involvement should be suspected if shoulder ROM deficits are characterized by lateral rotation that is the most limited, abduction that is also limited but is less than that seen in the limitation of lateral rotation, and medial rotation that is only minimally limited or is not limited at all.[28,29]

RANGE OF MOTION AND FUNCTIONAL ACTIVITY

A number of studies have been published that examined the motion of the shoulder complex during various activities. Both Safaee-Rad et al.[30] and Cooper et al.[31] analyzed upper extremity motion, including motion of the shoulder joint, during various feeding activities. Results from these two studies were fairly similar (Table 3.1), although Cooper et al.[31] combined data from the three feeding activities while Safaee-Rad et al.[30] reported their data separately. Other investigators who have examined shoulder motion during feeding activities have obtained reasonably similar results,[34,36] with the exception of Magermans et al.,[33] who reported their results as based on standards proposed by the International Society of Biomechanics (ISB),[42] making comparison of their

Table 3.1 SHOULDER ROM DURING FUNCTIONAL ACTIVITIES

FUNCTIONAL ACTIVITY	ELEVATION	PLANE OF ELEVATION*	MEDIAL ROTATION	LATERAL ROTATION	COMMENTS
Comb Hair					
Aizawa et al.[32]	110°	60°			Average maximal joint angle of 20 healthy subjects (10 M, 10 F, aged 18–34 years) during ADL task; ROM measured using an electromagnetic three-dimensional tracking system
Magermans et al.[33,‡]	90° ± 9°	59° ± 14°		70° ± 19°	Average maximal joint angle of 24 healthy female subjects (mean age 36.8 years) used during ADL task; ROM measured using Flock of Birds electromagnetic tracking device
Pearl et al.[34,§]	112° ± 10°	54° ± 27°			Average maximal joint angle of 8 "normal" subjects (aged 20–45 years) during ADL task; ROM measured using a 6° freedom spatial tracking system and electromagnetic sensors pinned to the humerus
van Andel et al.[35,‡]	98° ± 11°	64° ± 13°		81° ± 6°	Average maximal joint angle of 10 healthy adults (6 M, 4 F, mean age 28.5 years) during ADL task; ROM measured using Optotrak motion analysis system
Drink from Cup					
Aizawa et al.[32]	87°	80°			Average maximal joint angle of 20 healthy subjects (10 M, 10 F, aged 18–34 years) during ADL task; ROM measured using an electromagnetic three-dimensional tracking system
Safaee-Rad et al.[30,§]	43° ± 16° 31° ± 9°	90°[†] 0°[†]	23° ± 12°		Average maximal joint angle in 10 healthy men (aged 20–29 years) measured using three-dimensional measurement system
van Andel et al.[35,‡]	64° ± 11°	62° ± 8°		59° ± 5°	Average maximal joint angle of 10 healthy adults (6 M, 4 F, mean age 28.5 years) during ADL task; ROM measured using Optotrak motion analysis system
Eat					
Cooper et al.[31,§]	36° (M); 31° (F) 23° (M); 28° (F)	90°[†] 0°[†]	22° (M); 28° (F)		Average maximum joint angle in two groups (10 M, 9 F) of healthy adults (aged 18–50 years) measured using video-based three-dimensional measurement system during a combination of 3 feeding tasks
Henmi et al.[36,§]	43° ± 6°	90°[†]			Average maximum joint angle of 5 healthy adults (3 F; 2 M, aged 20–28 years) during ADL task; ROM measured using Vicon three-dimensional motion analysis system
Magermans et al.[33,‡]	74° ± 13°	60° ± 14°		49° ± 14°	Average maximal joint angle of 24 healthy female subjects (mean age 36.8 years) used during ADL task; ROM measured using Flock of Birds electromagnetic tracking device
Pearl et al.[34,§]	52° ± 8°	87° ± 29°			Average maximal joint angle of 8 "normal" subjects (aged 20–45 years) during ADL task; ROM measured using a 6° freedom spatial tracking system and electromagnetic sensors pinned to the humerus
Safaee-Rad et al.[30,§]	35° ± 20° (fork); 36° ± 14° 17° ± 6° (fork); 22° ± 7° (spoon)	90°[†] 0°[†]	18° ± 10° (fork); 17° ± 12° (spoon)		Average maximal joint angle in 10 healthy men (aged 20–29 years) measured using three-dimensional measurement system
Pour from Pitcher					
O'Neill et al.[37,§]	74° ± 8°	42° ± 8°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Grasp Top of Steering Wheel					
O'Neill et al.[37,§]	70° ± 8°	90° ± 7°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system

Table 3.1 SHOULDER ROM DURING FUNCTIONAL ACTIVITIES—cont'd

FUNCTIONAL ACTIVITY	ELEVATION	PLANE OF ELEVATION*	MEDIAL ROTATION	LATERAL ROTATION	COMMENTS
Hand behind Head					
Matsen et al.[38,§]	118°	13°			Data from single subject (unstated age and sex) measured using electromagnetic sensor pinned to humerus
Namdari et al.[39]				61.3° ± 2.3° dominant arm 56.3° ± 2.2° nondominant arm	20 healthy subjects (18 M, 2 F, aged 26–34 years) used during ADL task; ROM measured using the Polhemus 3Space Fastrak electromagnetic device
O'Neill et al.[37,§]	127° ± 11°	57° ± 16°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Hand to Back Pocket					
Petuskey et al.[40,§]	47° ± 11°	−90°[†]	27° ± 11°		Average maximum joint angle of 28 "normal" children (aged 9–12 years) measured using three-dimensional motion analysis system
van Andel et al.[35,‡]	48° ± 9°	52° ± 12°	102° ± 11°		Average maximal joint angle of 10 healthy adults (6 M, 4 F, mean age 28.5 years) during ADL task; ROM measured using Optotrak motion analysis system
Hand to Forehead					
Mackey et al.[41,§]	105° ± 10° 49° ± 15°	90°[†] 0°[†]			Average maximum joint angle of 10 healthy children (aged 6–12 years) during ADL task; ROM measured using three-dimensional motion analysis system
Hand to Mouth					
Mackey et al.[41,§]	70° ± 10° 46° ± 14°	90°[†] 0°[†]			Average maximum joint angle of 10 healthy children (aged 6–12 years) during ADL task; ROM measured using three-dimensional motion analysis system
O'Neill et al.[37,§]	87° ± 15°	77° ± 11°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Hand to Top of Head					
Petuskey et al. [40,§]	85° ± 17° 36° ± 13°	90°[†] 0°[†]	−32° ± 15°		Average maximum joint angle of 28 "normal" children (aged 9–12 years) measured using three-dimensional motion analysis system
Lift Object/Reach-Head Level/High Shelf					
Mackey et al.[41,§]	94° ± 13° 58° ± 10°	90°[†] 0°[†]			Average maximum joint angle of 10 healthy children (aged 6–12 years) during ADL task; ROM measured using three-dimensional motion analysis system
Matsen et al.[38,§]	93°	66°			Data from single subject (unstated age and sex) measured using electromagnetic sensor pinned to humerus
Namdari et al.[39]				38.1° ± 2.2° soup can dominant arm 41.8° ± 2.6° 1-gallon container dominant arm 32.1° ± 1.7° soup can nondominant arm 41.6° ± 1.6° 1-gallon container nondominant arm	20 healthy subjects (18 M, 2 F) (aged 26–34 years) used during ADL task; ROM measured using the Polhemus 3Space Fastrak electromagnetic device
O'Neill et al.[37,§]	105° ± 7°	61° ± 7°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system

Continued

Table 3.1 SHOULDER ROM DURING FUNCTIONAL ACTIVITIES—cont'd

FUNCTIONAL ACTIVITY	ELEVATION	PLANE OF ELEVATION[*]	MEDIAL ROTATION	LATERAL ROTATION	COMMENTS
Lift Object/Reach-Shoulder Level					
Matsen et al.[38,§]	78°	86°			Data from single subject (unstated age and sex) measured using electromagnetic sensor pinned to humerus
Namdari et al.[39]				39.1° ± 2.1° 1-gallon container dominant arm 33.9° ± 1.9° soup can dominant arm 38.5° ± 1.9° 1-gallon container nondominant arm 30.8° ± 1.2° soup can nondominant arm	20 healthy subjects (18 M, 2 F, aged 26–34 years) used during ADL task; ROM measured using the Polhemus 3Space Fastrak electromagnetic device
O'Neill et al.[37,§]	62° ± 7°	66° ± 6°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Perineal Care					
Magermans et al.[33,‡]	35° ± 10°	−67° ± 24°	105° ± 25°		Average maximal joint angle of 24 healthy female subjects (mean age 36.8 years) used during ADL task; ROM measured using Flock of Birds electromagnetic tracking device
Pearl et al.[34,§]	38° ± 10°	−86° ± 13°			Average maximal joint angle of 8 "normal" subjects (aged 20–45 years) during ADL task; ROM measured using a 6° freedom spatial tracking system and electromagnetic sensors pinned to the humerus
O'Neill et al.[37,§]	31° ± 3°	−77° ± 11°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Reach Up Back					
Pearl et al.[34,§]	56° ± 13°	−69° ± 11°			Average maximal joint angle of 8 "normal" subjects (aged 20–45 years) during ADL task; ROM measured using a 6° freedom spatial tracking system and electromagnetic sensors pinned to the humerus
Reach to Receive Change					
Petuskey et al.[35,§]	32° ± 17° 5° ± 10°	90°[†] 0°[†]		12° ± 21°	Average maximum joint angle of 28 "normal" children (aged 9–12 years) measured using three-dimensional motion analysis system
Shampoo Hair					
Henmi et al.[36,§]	64° ± 9°	90°[†]			Average maximum joint angle of 5 healthy adults (3 F, 2 M, aged 20–28 years) during ADL task; ROM measured using Vicon three-dimensional motion analysis system
Tie Shoes					
O'Neill et al.[37,§]	72° ± 14° (R) 63° ± 12° (L)	88° ± 17° (R) 73° ± 7° (L)			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
Tuck in Shirt					
Namdari et al.[39]			88.3° ± 9.1° dominant arm 86.9° ± 8.7° nondominant arm		20 healthy subjects (18 M, 2 F, aged 26–34 years) used during ADL task; ROM measured using the Polhemus 3Space Fastrak electromagnetic device
Pearl et al.[34,§]	57°	−54°			Data from single subject (unstated age and sex) measured using electromagnetic sensor pinned to humerus
Wash Axilla					
Magermans et al.[33,‡]	53° ± 9°	100° ± 9°		15° ± 7°	Average maximal joint angle of 24 healthy female subjects (mean age 36.8 years) used during ADL task; ROM measured using Flock of Birds electromagnetic tracking device

Table 3.1 SHOULDER ROM DURING FUNCTIONAL ACTIVITIES—cont'd

FUNCTIONAL ACTIVITY	ELEVATION	PLANE OF ELEVATION*	MEDIAL ROTATION	LATERAL ROTATION	COMMENTS
Pearl et al.[34,§]	52° ± 14°	104° ± 12°			Average maximal joint angle of 8 "normal" subjects (aged 20–45 years) during ADL task; ROM measured using a 6° freedom spatial tracking system and electromagnetic sensors pinned to the humerus
Wash Face					
Henmi et al.[36,§]	50° ± 7°	90°[†]			Average maximum joint angle of 5 healthy adults (3 F, 2 M, aged 20–28 years) during ADL task; ROM measured using Vicon three-dimensional motion analysis system
Wash Opposite Shoulder					
Matsen et al.[38,§]	71°	128°			Data from single subject (unstated age and sex) measured using electromagnetic sensor pinned to humerus
O'Neill et a[37,§]	69° ± 11°	124° ± 9°			Average joint angle of 10 healthy subjects (unstated age) measured using 3Space Isotrak system
van Andel et al.[35,‡]	53° ± 3°	102° ± 11°	27° ± 9°		Average maximal joint angle of 10 healthy adults (6 M, 4 F, mean age 28.5 years) during ADL task; ROM measured using Optotrak motion analysis system

*Plane of elevation defines the position of the humerus in the horizontal plane such that shoulder abduction occurs in the 0-degree plane, shoulder flexion occurs in the 90-degree plane, and shoulder extension occurs in the −90-degree plane.

[†] 90° = shoulder flexion; 0° = shoulder abduction; −90° = shoulder extension.

[‡] Humeral elevation (does not include scapulothoracic motion).

[§] Shoulder complex motion (glenohumeral and scapulothoracic motion combined).

Vicon Three-Dimensional Motion Analysis System by Vicon Motion Systems and Peak Performance Inc., Oxford, United Kingdom.

3Space Isotrak by Polhemus 3Space, Colchester, Vt.

Flock of Birds electromagnetic tracking device by Ascension Technology Corp, Burlington, Vt.

Optotrak Motion Analysis system by Northern Digital Inc., Ontario, Canada.

ADL, Activities of daily living.

results with results from previous studies impossible. Several subsequent studies have reported their results as based on ISB standards.[35,40] Caution should be used in making comparisons between studies that report data based on ISB standards vs studies that use more conventional descriptions of motion because the results are not likely to be comparable.

When results of studies focusing on shoulder motion are compared during functional activity, the reader must pay close attention to the motion that is being measured. Some investigators measure total motion of the shoulder complex, while others attempt to separate glenohumeral from scapulothoracic and other motions of the joints of this complex. Each of the studies reported in Table 3.1 is labeled as to the type of motion measured.

In 1992, Pearl et al.[34] proposed a system for describing motion of the shoulder that involved using a global positioning diagram in which planes of humeral motion were related to longitude and latitude lines on a globe. As part of this system, these investigators defined the plane of elevation as it corresponds to longitudinal markers on a globe, with the coronal plane (shoulder abduction) being the 0-degree plane, the anterior sagittal plane (shoulder flexion) being the +90-degree plane, and the posterior sagittal plane (shoulder extension) being the −90-degree plane. The angle of elevation was defined as corresponding to latitude markers and as "the angle between the unelevated and the elevated humerus."[34] Thus an individual positioned in 45 degrees of shoulder abduction would have an angle of elevation of 45 degrees in the 0-degree plane of elevation. Many subsequent groups have reported data on functional shoulder motion using the conventions described by Pearl et al.[34] Both angle of elevation and the plane of elevation data are reported in Table 3.1. For authors who did not report plane of elevation data, shoulder flexion, abduction, and extension were converted to plane of elevation using definitions provided by Pearl et al.[34]

Table 3.1 contains the results of several studies that examined shoulder motion used during a variety of functional activities. Most of the studies from which data were derived were performed in young, healthy adults, although some data were obtained in children. Essentials of the method and study populations used are included in the table. Caution should be used in extrapolating these data to the general population because the sample sizes for all of the studies were small. For more in-depth information on each study, the reader is directed to the reference list at the end of this chapter. Additional information on shoulder range of motion required to perform functional tasks may be found in the review article by Oosterwijk and colleagues.[43] Figs. 3.5–3.7 demonstrate examples of shoulder motion used during selected functional tasks.

Fig. 3.5 Shoulder motion used when tucking in a shirt.

TECHNIQUES OF MEASUREMENT: SHOULDER FLEXION/EXTENSION

Shoulder flexion is a composite of motions that occur at multiple joints that make up the shoulder complex. Although some texts attempt to isolate the flexion that occurs at the glenohumeral joint and to measure that motion alone, no such attempt to isolate glenohumeral motion is presented in this text because such isolated movement does not occur past the first 30 degrees or so of shoulder flexion in normal motion.

Preferred patient positions for measuring shoulder flexion and extension are supine and prone, respectively, because of the greater stabilization of the spine that occurs in those positions compared with other positions in which flexion and extension can be measured. Measurement of flexion and extension also can be performed with the patient in the standing, sitting, or side-lying position. The American Academy of Orthopaedic Surgeons (AAOS) advocates measuring shoulder flexion and extension with the patient standing but states, "If spine and pelvic motion cannot be controlled, external rotation and elevation should be assessed with the patient supine."[44] Reliability of measurements of shoulder flexion taken with the patient supine is generally greater than for the same measurements taken with the patient in an upright position.[45] When shoulder flexion and extension are measured,

Fig. 3.6 Shoulder motion used to drink from a cup.

Fig. 3.7 Shoulder motion used to wash the opposite axilla or apply deodorant.

regardless of the position used, care should be taken to prevent extension of the spine in the case of shoulder flexion and flexion of the spine in the case of shoulder extension, which artificially inflate the resulting measurement and increase measurement error.

TECHNIQUES OF MEASUREMENT: SHOULDER ABDUCTION

As is the case for shoulder flexion, shoulder abduction is a composite movement, and no attempt is made in this text to isolate and measure the glenohumeral component of shoulder abduction. In obtaining the full range of shoulder abduction, the patient's glenohumeral joint should be placed in a neutral or, preferably, an externally rotated position. When abduction is attempted with the glenohumeral joint in internal rotation, the greater tuberosity of the humerus impinges upon the acromion, greatly restricting the range of shoulder abduction.[16] Because of issues of stabilization in the spine, shoulder abduction is best measured with the patient in a supine position, although measures of abduction in standing have also demonstrated high reliability.[45] Other positions for measuring abduction include standing, sitting, and prone, with standing being the position advocated by the AAOS.[44] During any measurement of shoulder abduction, regardless of the position used, care should be taken to prevent lateral flexion of the spine by the patient, because this motion artificially inflates the range of shoulder abduction obtained.[46]

TECHNIQUES OF MEASUREMENT: SHOULDER MEDIAL-LATERAL ROTATION

The AAOS recommends measuring lateral rotation of the shoulder with the patient's shoulder placed in 0 or 90 degrees of abduction; medial rotation is measured with the shoulder in 90 degrees of abduction.[44] Other authors have advocated a slightly abducted position of the shoulder during measurement of medial-lateral rotation.[47] Because studies have demonstrated that range of lateral rotation of the shoulder increases and the range of medial rotation decreases with the amount of shoulder abduction used during the measurement,[14,47–49] standardized techniques for patient positioning should be followed for these as for all other goniometric procedures. In this text, shoulder medial and lateral rotation is measured with the patient positioned in 90 degrees of shoulder abduction. However, some patients with shoulder pathology are unable to attain 90 degrees of shoulder abduction, and in such cases, alternative positioning may be required. When used, such alternative positioning should be clearly documented. Reliability of rotation measurements, whether the shoulder is in 0 or 90 degrees of abduction, appears to be similarly high.[50,51]