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#### ANATOMY AND FUNCTION OF SCAPULA AND SHOULDER GIRDLE-REVIEW OF CURRENT LITERATURE

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#### SUMMARY

##### Introduction

Shoulder girdle is a complex structure composed of clavicle, scapula and proximal humerus. Sternoclavicular, acromioclavicular and glenohumeral (GH) joints and scapulothoracic articulation connect them with each other. Soft tissues – muscles, fasciae and ligaments surround them. Precise neuronal coordination of shoulder girdle allows positioning elbow and hand in space.

##### Aim

The aim of this study was to discuss anatomy and function of scapula and shoulder girdle.

##### Material and methods

Research was based on the sources of anatomical knowledge including anatomy textbooks, scientific research papers and reviews and own experiences of surgical anatomy and function of scapula.

##### Results

Scapula articulates with proximal humerus, clavicle and chest. Scapulothoracic articulation is not a classic joint but it allows gliding movements of the scapula over chest. Those include protraction, retraction, lowering, elevation, upward and downward rotation and tilts. These depend on the coordinated muscles function. Proper

#### ANATOMIA I FUNKCJA ŁOPATKI ORAZ OB- RĘCZY BARKOWEJ – PRZEGLĄD AKTUAL- NEJ LITERATURY

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#### STRESZCZENIE

##### Wstęp

Obwód barkowa składa się z obojczyka, łopatki i bliższego końca kości ramiennej, które łączą się poprzez stawy: mostkowo-obojczykowy, barkowo-obojczykowy, ramienny oraz żebrowo-łopatkowy. Struktury te otoczone są tkankami miękkimi – mięśnie, powięź i więzadła. Dokładna koordynacja neuronalna obręczy barkowej pozwala na pozycjonowanie łokcia i dłoni w przestrzeni.

##### Cel

Celem niniejszej pracy było omówienie anatomii i funkcji łopatki i obręczy barkowej.

##### Materiał i metody

Opracowanie oparto na współczesnej literaturze dotyczącej anatomii i funkcji łopatki oraz własnych doświadczeniach z zakresu anatomii chirurgicznej i ocenie funkcjonalnej barku.

##### Wyniki

Łopátka łączy się z bliższym końcem kości ramiennej, obojczykiem i klatką piersiową. Staw żebrowo-łopatkowy nie ma klasycznej budowy, ale umożliwia ruchy „poślizgowe” łopatki w stosunku do powierzchni klatki piersiowej. Należą do nich: protrakcja, retrakcja, obniżanie, unoszenie oraz ruchy rotacyjne obręczy barkowej. Funkcje

scapula motion contributes significantly to the shoulder girdle movements.

### Conclusions

Scapula is important component of shoulder girdle. However doctors and physiotherapists often omit its role. One has to remember that if the function and motion of shoulder girdle would rely only on GH joint – it would never reach such extent that is observed in physiologic conditions. Lack of knowledge of shoulder girdle anatomy and function, including scapular element, impairs diagnosis and treatment processes of shoulder disorders.

**Keywords:** anatomy of shoulder girdle, anatomy of scapula, function

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### Introduction

The shoulder girdle is a complex anatomical structure that allows to position and to control the upper limb (hand and elbow) in a very wide range of positions in space in regard to the human body. The physiologic range of motion (ROM) of the shoulder exceeds by far the range of motion necessary for most of the daily tasks. It composed of four joints: sternoclavicular joint (SC), acromioclavicular joint (AC), glenohumeral joint (GH) and scapulothoracic articulation (ST). All of them are integrated, linked and act together in a physiologic ROM of the shoulder. Those joint connects sternum, clavicle, scapula, humerus and thorax. Proper function of the shoulder depends on joints, osseous structures of the shoulder together with soft tissues surrounding them. Active ROM and stability of the girdle rely on proper control and action of the muscles. Disorders of one or more of the components of the shoulder girdle may impair significantly

te zależne są od prawidłowej koordynacji mięśniowo-nerwowej. Fizjologiczna ruchomość łopatki jest istotną składową poprawnego toru ruchu obręczy barkowej.

### Wnioski

Łopaska jest ważnym elementem obręczy barkowej. Jednakże jej rola jest często pomijana przez lekarzy i fizjoterapeutów w procesie leczenia. Należy pamiętać, iż ograniczanie funkcji i ruchu obręczy barkowej tylko do ćwiczeń stawu ramiennego oznacza brak możliwości uzyskania fizjologicznego zakresu ruchu barku. Brak znajomości budowy anatomicznej i funkcji obręczy barkowej, w tym przede wszystkim łopatki, może zaburzyć proces diagnozowania i leczenia patologii tej okolicy.

**Słowa kluczowe:** anatomia obręczy barkowej, anatomia okolicy łopatki, funkcja

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its function leading to decreased dexterity of the whole upper limb (Rockwood 2009; Terry and Chopp 2000).

### Aim

The goal of this review was to present the anatomy and function of scapula and its relations to the other elements of the shoulder girdle. The idea was to particularly emphasize its importance, describe its anatomical features and role in shoulder girdle. Clinicians often omit them in diagnosis, clinical evaluation and treatment of shoulder disorders.

### Material and methods

Research was based on the sources of anatomical knowledge including anatomy textbooks, scientific research papers and reviews. Own experiences of surgical anatomy of shoulder girdle and function of this structure were included. Attention was

focused on anatomy of scapula, scapulothoracic articulation and their movements.

## Results

### *Sternoclavicular joint (SC)*

SC joint is the only articular connection between the shoulder girdle and axial skeleton. Synovial joint has two cavities separated by disc, which spans from the first rib to the superior part of medial clavicle. Articular disc together with costoclavicular ligament prevents medial migration of clavicle. Costoclavicular ligament prevent excessive rotations of clavicle – both upward and downward. Interclavicular ligament connects medial ends of both clavicles and stabilize superior side of the SC joint. Sternoclavicular ligaments strengthen the anterior and posterior joint capsule. SC joint anatomy allows to frontal plane rotation, movements in horizontal plane and rotation in long axis of the clavicle. Because of close proximity of large vessel SC joint posterior dislocation might be life-threatening injuries (Bearn 1967; Peat 1986; Terry and Chopp 2000).

### *Clavicle*

Clavicle is “S” shaped bone that connects upper limb with axial skeleton through SC joint. The other important function is protection of the neurovascular structures that lies beneath it. The medial part articulates with sternum, middle part transfers load, while lateral part is connected to acromion. Clavicle serves also as a muscle attachment site for pectoralis major, trapezius, deltoid, subclavius and sternocleidomastoideus (Ljunggren 1979; Terry and Chopp 2000).

### *Acromioclavicular joint (AC)*

AC joint might be completely or partially divided into two cavities separated by the disc. To provide stability – joint capsule is reinforced with AC ligaments – from inferior, superior, anterior and posterior sides. Of those the superior is the strongest. Coracoclavicular ligaments provide essential additional stability. During traumatic AC separations

those structures are injured. The grade of injury depends on extent of their involvement during traumatic episode. AC joint arthritis is a common radiological and/or clinical finding. Heavy loads that are transferred through that joint cause it. It might be symptomatic or not (Peat 1986; Terry and Chopp 2000).

### *Scapula*

Scapula is a triangular flat bone that lies on the posterior – lateral surface of the thorax between second and seventh rib. It is important to remember that it is not parallel to frontal plane. The scapular body forms 30–45 degree angle with frontal plane.

Anatomically it has three borders – medial, superior and lateral; three angles – superior, inferior and lateral; two surfaces – dorsal and costal. There are three prominent structures/processes arising from the scapula body – coracoid, acromion and scapular spine. Laterally scapular spine forms acromion, which is connected to clavicle by the AC joint.

The lateral angle consists of scapular neck, coracoid and glenoid. Glenoid fossa articulates with proximal humerus. GH joint capsule, labrum and glenohumeral ligaments arise from the glenoid. Acromion forms roof of GH joint over rotator cuff. Anteriorly tip of coracoid is in close proximity to GH joint. Coracoid is directed anteriorly, inferiorly and laterally. It is important as an origin of short head of biceps brachii, coracobrachialis and lateral attachment of pectoralis minor. Coracoclavicular ligaments origin from its upper surface (conoid and trapezoid ligaments). They are essential for AC joint stability as mention above. Acromioclavicular and coracohumeral ligaments origin from the lateral surface of coracoid process. Acromioclavicular ligaments together with acromion and coracoid form arch that prevents superior migration of humeral head.

Borders of acromion are origin of deltoid. Medial border articulates with clavicle forming AC joint.

Scapular spine divides dorsal surface into smaller supraspinatus fossa and larger infraspinatus fossa. The former is the origin of the supraspinatus muscle and later of infraspinatus muscle and teres minor. Scapular spine, acromion and lateral clavicle are proximal origins of the deltoid muscle. Apart from the deltoid origin, scapular spine serves as an attachment of trapezius muscle.

The medial border of the scapulae is lateral attachment of the levator scapulae, rhomboid major and minor and serratus anterior. The lateral border of scapula is origin of the following muscles beginning from neck region – long head of triceps and teres minor.

The superior border is split in the lateral part by suprascapular notch.

Flat costal surface of the scapula is origin of the subscapular muscle – subscapular fossa.

The inferior angle is attachment of teres major and in some cases one site of origins of latissimus dorsi (Frank *et al.* 2013; Rockwood 2009; Terry and Chopp 2000).

#### *Scapulothoracic articulation*

As mentioned above scapula has not any osseous and ligamentous direct connections to the chest. It connected indirectly to the chest through SC joint, clavicle and AC joint. They allow scapula to follow and support humerus during arm ROM. Movements of scapula depend on the proper gliding on the surface of the chest. Concave surface of the scapula moves over convex surface of ribs. The scapulothoracic articulation is not a typical joint, because it lack joint features such as cartilage, capsule and ligaments. The space in-between anterior surface of the scapula and posterolateral surface of the thorax contains soft tissues such as muscles and bursae. The motion depends on smooth gliding of the subscapularis muscle over serratus anterior and bursae. There are three bursae described around scapula: first between serratus anterior and the chest wall, and the

other two at superior and at inferior angle of scapula. Scapulothoracic articulation motion increases shoulder ROM. In general, during shoulder elevation at approximate ratio of 1 deg. in scapulothoracic connection for each 2 deg. elevation in glenohumeral joint (Frank *et al.* 2013; Mottram 1997; Paine and Voight 2013; Terry and Chopp 2000).

#### *Movements of scapula*

The most popular way to describe the motion of scapula is to relate it to the chest wall. There are eight types of scapulothoracic movements described. The forward and backward motions along the chest wall are respectively protraction and retraction. Scapula can be also moved upwards – elevation and downwards – depression. It can also be rotated upward and downward in scapular plane. The other described movements are tilts – both in vertical and frontal axis (Paine and Voight 2013; Peat 1986).

#### *Muscles*

Scapula provides attachment for seventeen different muscles. (Frank *et al.* 2013; Terry and Chopp 2000) Biceps brachii (long and short head), triceps brachii (long head), coracobrachialis, supraspinatus, infraspinatus, teres minor, teres major, deltoid are the muscles that connects scapula with humerus. They are responsible for the motion of the arm in reference to scapular position.

The other group of muscles – pectoralis minor, trapezius, minor and major rhomboids, levator scapulae, serratus anterior and subclavius connect the scapula with chest and axial skeleton. They are responsible for the scapulothoracic motion. Latissimus dorsi and pectoralis major are the muscles that join axial skeleton with humerus and are also important for proper shoulder function. It is important to remember that scapula is not connected to the thorax or spine with by any static constraints such as ligaments or osseous structures. That is why its proper position and motion against

chest depends directly on the action and balance of those muscles.

The detailed description is focused on the muscles responsible for scapula function (Frank *et al.* 2013; Rockwood 2009; Terry and Chopp 2000).

Serratus anterior muscle is innervated by long thoracic nerve. Its origin are first eight to ten ribs anteriorly and medial attachment is the medial border of the costal surface of scapula and laterally. It has two parts – lower and upper. It is responsible for scapula protraction and stabilization during elevation. The lower part together with trapezius act in elevation of the shoulder.

Trapezius is innervated by the accessory nerve. It is the largest of the muscle surrounding scapula, triangular in shape. The origins are: base of the skull, nuchal ligament, spinous processes C7-Th12. Laterally it attaches to the acromion, clavicle and scapular spine. Its upper part acts as a scapular elevator, while lower part protracts and assists in shoulder elevation by upward rotation of the scapula.

Rhomboid major and minor muscles are innervated by dorsal scapular nerve. Their origins are respectively spinous processes Th2-5 and lower part of nuchal ligament/spinous processes C7-Th1. Laterally they attaches to the dorsal surface of medial border of scapula. They both elevate scapula and retracts it.

Levator scapula is innervated by C3 and four spinal nerves. Its origins are transverse processes of the cervical vertebrae. It attaches laterally to the upper part of the dorsal surface of the medial border of scapula. It elevates superior angle of scapula.

Pectoralis minor muscle is innervated by medial pectoral nerve. Its origins are second to fifth ribs. It attaches laterally to the medial border of the coracoid. Pectoralis minor serves as protractor and downward rotator of the scapula.

Deltoid muscle is innervated by axillary nerve. It is formed by three proximally distinct parts. Anterior part origins proximally

at lateral end of clavicle, lateral part at edge of acromion and posterior part at scapular spine. Distally deltoid is attached to deltoid tuberosity. Together with rotator cuff deltoid acts in arm elevation in plane of scapula (Peat 1986).

Latissimus dorsi muscle is innervated by thoracodorsalis nerve. It is very wide muscle. Its origins are vertebrae Th6-Th12, L1-5 and sacral vertebrae – supraspinous ligament, lower ribs IX/X–XII and posterior iliac crest. It might also attach to lower angle of scapula. Its insertion site is floor of intertubercular groove of the humerus. Latissimus dorsi is adductor, extensor and internal rotator of arm.

The rotator cuff consists of a group of four muscles with associated tendons: supraspinatus muscle, infraspinatus muscle, teres minor and subscapularis muscle. All of them join scapula and humerus.

Supraspinatus muscle is innervated by suprascapularis nerve. Its origin is supraspinatus fossa. It spans from there laterally and anteriorly to the upper surface of greater tuberosity and joint capsule. Together with deltoid it acts as elevator of the arm in scapular plane.

Infraspinatus muscle is innervated by suprascapularis nerve. Infraspinatus muscle originates in upper 2/3 of infraspinatus fossa. Laterally it is attached to the greater tuberosity – middle facet. The main function of this muscle is to rotate humerus externally. It also provides joint protection against posterior migration of humeral head.

Teres minor muscle is innervated by axillary nerve. It originates on the dorsal surface of the lateral border of scapula. It spans laterally to the greater tuberosity its inferior posterior part. Infraspinatus muscle is external rotator of the shoulder.

Subscapularis muscle is innervated by the upper and lower subscapular nerve. It origins in subscapular fossa – located on the medial 2/3 of the anterior surface of scapula. Laterally it is attached to the lesser tuberosity. Also laterally tendon fibers blends

with anterior part of the glenohumeral joint capsule. Subscapularis muscle serves as internal rotator of the arm.

Biceps brachii is innervated by musculocutaneous nerve. Biceps brachii is composed of two muscle heads – short and long. They are clearly distinct proximally. The long biceps brachii head originates on the supraglenoid tubercle of the scapula. It is very important to remember that it is also closely attached to the superior labrum of the glenohumeral joint. Short head of biceps originates on the coracoid process. Distally both heads are attached to the radius tuberosity. Distally it is much more difficult to discriminate between both heads. Concerning biceps brachii function within the shoulder – long head of biceps is depressor of the humeral head.

Pectoralis major is a large muscle on the anterior surface of the chest. Medial and lateral pectoral nerves innervate it. Its medial attachments are cartilage of the first seven ribs, sixth rib, sternum, aponeurosis of the external oblique muscle and medial clavicle. Laterally it is attached to the greater tuberosity crest. It acts as adductor and internal rotator of the arm (Paine and Voight 2013; Terry and Chopp 2000).

#### *Proximal humerus*

Proximal humerus is the last osseous part of shoulder girdle. Semi sphered shape of humeral head in combination with small glenoid allows extensive range of motion. Three-dimensional analysis of the humeral head describes its relations to the middle and distal part of humerus. The humeral head is retroverted in horizontal plane and inclined in frontal plane. The anatomic neck separates articular surface from lesser and greater tuberosity. Tuberosities are separated by bicipital groove – that contains tendon of the long head of biceps brachii on its way from GH joint to the arm. Subscapular muscle attaches to the lesser tuberosity. Greater tuberosity has three facets for supraspinatus, infraspinatus

and teres minor muscles. Region below tuberosities is known as surgical neck. It is often site of fracture. Lesser tuberosity extends downwards forming anterior lip of bicipital groove. It is site of attachment of teres major. Intertubercular groove is site of insertion of latisimus dorsi (Kronberg *et al.* 1990; Peat 1986; Terry and Chopp 2000).

#### *Glenohumeral joint*

GH joint is multi axial joint, type of “ball and socket” joint. There is disproportion between large articular surface of humeral head and small of scapular glenoid. The contact area of humeral head comparing to glenoid surface ranges between 25–30%. Because of those relations GH joint needs multiple stabilizers to prevent its instability.

Static stabilizers are joint capsule, labrum and ligaments. Glenoid labrum is triangular on cross section structure. It is composed of dense fibrous tissue and increases surface that contacts glenoid with humeral head. It also deepens glenoid. Capsule is large comparing to the joint volume. It allows extensive range of motion, but it gets tight in extreme positions. Ligaments reinforce capsule. Strictly anterior ligaments are coracohumeral, superior, middle, inferior (anterior band) GH ligaments. Posterior band of inferior GH ligament is located in inferior posterior part of the capsule. Additional stability of GH joint depends on negative pressure within the joint space. It causes suction effect (Gibb *et al.* 1991; Terry and Chopp 2000).

While static stabilizers of GH joint provides stability in extreme ROM positions, active stabilizers provide stability in mid ROM. The active stabilizers are muscles of rotator cuff – supraspinatus, infraspinatus, subscapularis and teres minor (Terry and Chopp 2000).

#### **Discussion**

The knowledge and understanding of shoulder girdle anatomy is extremely important for orthopedic and trauma surgeons

and physiotherapists. Apart from proper diagnosing shoulder disorder, precise understanding of shoulder biomechanics is necessary for both conservative and surgical treatment. Snapping scapula syndrome is example where primary treatment includes physiotherapy based on regaining physiologic muscular control of the scapula. Surgical muscle transfer techniques for treatment of muscular palsies around scapula like trapezius or serratus anterior, also require excellent understanding of scapula anatomy and function.

It is important to remember that if the motion of shoulder girdle would rely only on GH joint – it would never reach such extent that is observed in physiologic conditions. This extra motion is provided by the other nonetheless important components of the shoulder girdle – especially scapula and its scapulothoracic articulation. If it is forgotten during rehab program, the results might be poor or even the symptoms may increase.

The knowledge of shoulder anatomy changes, improves with successive research projects follow by scientific publications. So it is important to follow it and keep up to date (Crowe and Elhassan 2015; Frank *et al.* 2013).

### **Conclusions**

- Shoulder girdle enables to position hand in space in reference to the trunk.
- The structure of most value, frequently underestimated by both doctors and physiotherapists is scapula.
- Scapula forms bony link between clavicle and humerus.
- Apart from acromioclavicular joint there is not any other articular/ligamentous connection to the axial skeleton.
- Scapula is stabilized and controlled by muscles.
- Not only memory of scapula but also precise knowledge of its anatomy is essential form contemporary complex treatment of shoulder disorders.



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