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Dysfunctional positioning of the shoulder girdle and its impact on the biomechanics of the upper limb

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Anatomy of the shoulder joint

Shoulder joint (articulatio glenohumeralis) is the connection between the humerus and the scapula. The joint socket is formed by a cavity in the scapula – the glenoid cavity, which is significantly flattened and small. To increase the contact surface and stability of the joint, the socket is deepened by the glenoid labrum glenoidale), which contributes to the sealing and stabilization of the head of the humerus.

The joint head is formed by the head of the humerus (caput humeri), which is almost half a sphere with a radius of about 2.5 cm. The surface area of the humeral head is about four times larger than the surface area of the glenoid, resulting in actual surface contact of only about one-third. This anatomical structure allows for a wide range of motion at the expense of relative joint instability.

The stability of the shoulder joint is supported by numerous ligaments, the most important of which are:

1. The coracohumeral ligament (ligamentum coracohumerale) – connects the coracoid process of the scapula with the humerus, limiting excessive abduction and rotation movement.

2. The glenohumeral ligaments (ligamenta glenohumeralia), which are divided into:

- Superior ligament
- Median ligament
- Inferior ligament

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- Constituting the main structures limiting excessive displacement of the humeral head, especially in terms of rotation and translation.

Muscles of the upper limb girdle:
These muscles play a key role in the movement and stabilization of the shoulder joint:

1. Deltoid muscle (m. deltoideus)

- The main muscle that abducts the arm to the horizontal (approx. 90°).
- With further abduction, the humerus comes into contact with the acromion of the scapula, which limits movement.
- Movement above the horizontal level is mainly due to the activity of the clavicular joints.
- Shoulder section – responsible for abduction of the arm.
- Clavicle part – performs internal rotation and adduction.
- Spine part – is responsible for external rotation and posterior adduction.

2. Supraspinatus muscle

- Initiates abduction of the arm.
- Participates in external rotation of the shoulder.

3. Infraspinatus muscle

- Responsible for external rotation of the arm.
- The upper part of the muscle also participates in abduction and flexion of the arm.

4. Teres minor muscle (m. teres minor)

- Functions as an external rotator of the shoulder.

5. Teres major muscle (m. teres major)

- Lowers the raised arm.
- Brings the arm backward.
- Rotates the arm inward.

6. Subscapular muscle (m. subscapularis)

- Main internal rotator of the shoulder.
- It is also responsible for adduction of the arm [1, 2].

Body posture is the arrangement of body segments in space that enables maintaining balance in the musculoskeletal system [3, 4, 5].

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Rounded shoulder posture (RSP) is one of the most common postural disorders in which the line of gravity shifts forward. This type of change leads to incorrect positioning of the head and shoulders relative to the vertical axis of the body, resulting in poor posture [3, 4, 5, 6].

Incorrect head and shoulder positioning is associated with increased muscle strain, the risk of developing degenerative disc disease, back pain and chronic shoulder dysfunctions [5,7]. RSP often co-occurs with disorders in the position of the shoulder blades – their protrusion and forward tilt leads to increased muscle tension [8, 9].

According to the literature, the muscles most susceptible to excessive tension during RSP include the upper trapezius muscle and the pectoralis minor muscle [3, 4].

Prolonged sitting in a static position further exacerbates postural abnormalities. Therefore, office workers are particularly susceptible to developing postural defects. Chronic work in static conditions leads to poor body posture over time, which can result in reduced functionality and work efficiency. Rounded shoulder posture (RSP) is a postural defect in which the acromions are displaced forward of the line of gravity, the shoulders protrude and rotate inward, and tilt forward [12]. One factor contributing to the development of this type of abnormality is prolonged smartphone use. This activity promotes poor posture, including a protruding neck, rounded shoulders, and a hunched back [13].

Changes in the position of the shoulder girdle resulting from RSP may affect the functioning of the complex anatomical system encompassing the head, neck, and shoulders. This may lead to the development of various ailments and disorders within these structures [14].

Reduced physical activity and inappropriate postural habits in everyday life can lead to changes in muscular and skeletal structures, resulting in their incorrect alignment [10]. One of the common postural disorders is forward head posture (FHP) , which is characterized by excessive forward head displacement relative to the vertical axis of the body [11].

The dominant influence of evidence-based medicine (EBM) is reflected in the need for detailed description and precise measurement of clinical parameters – even qualitative data such as patient satisfaction or cosmetic effect require clear definition and measurability [15].

In adolescent idiopathic scoliosis (AIS), important aesthetic aspects include trunk symmetry, sagittal and frontal balance, and shoulder balance [16]. Although there is general agreement on the crucial importance of shoulder balance, there is still a lack of consensus on what exactly constitutes optimal shoulder symmetry in patients with AIS.

Traditionally, shoulder symmetry has been assessed by radiological examinations using various measurement methods [16, 17, 18]. Numerous radiological parameters used to assess shoulder balance have been described and their diagnostic usefulness compared. These include: T1 vertebral inclination, clavicular angle, coracoid process height difference, trapezius length, first rib and clavicle height,

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thoracic-clavicular intersection difference, first rib angle, clavicular inclination angle difference, and radiological shoulder height [19-24].

Unfortunately, as studies have shown, clinical assessment of shoulder balance does not always correlate with the results of radiological measurements, which indicates the need for further improvement of assessment methods [16, 25, 26].

Muscles responsible for scapular depression (shoulder lowering)

1. Trapezius muscle – lower part (m. trapezius, pars inferior)
    - It is responsible for pulling the scapula downward and medially.
    - It plays an antagonistic role to the upper part of the trapezius muscle.
    - It is involved in the upward rotation of the scapula, cooperating with the serratus anterior muscle during lifting of the upper limb.
2. Pectoralis minor muscle (m. pectoralis minor)
    - It attaches to the coracoid process of the scapula and ribs III–V.
    - It allows for retraction and slight downward movement of the scapula, participating in both depression and protraction of the scapula.
3. Latissimus dorsi muscle (m. latissimus dorsi)
    - Mainly responsible for adduction and extension of the arm, but with a stabilized upper limb it can assist in shoulder depression.
4. Subclavicular muscle (m. subclavius)
    - Although its influence is limited by stabilizing the clavicle, it may indirectly participate in clavicular and shoulder depression.
5. Serratus anterior muscle – lower fibers (m. serratus anterior – pars inferior)
    - It plays an important role in the rotation and stabilization of the scapula.
    - It participates in the depression of the scapula, especially during the final phase of raising the arm above the shoulder level.

Clinical significance:

Weakness of the lower trapezius and serratus anterior muscles can lead to excessive scapular elevation, impaired shoulder mechanics, and the development of subacromial impingement syndrome [1, 2].

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Muscles responsible for scapular elevation (shoulder lift)

1. Trapezius muscle – upper part (m. trapezius, pars descendens)

    - The main force lifting the shoulder.
    - It attaches to the occiput, the spinous processes of the cervical vertebrae, and the lateral part of the clavicle.
    - It cooperates with the lower part of the trapezius muscle in upward rotation of the scapula.

2. Levator muscle of the scapula (m. levator scapulae)

    - Raises the superior angle of the scapula and tilts the neck to the side.
    - It attaches to the transverse processes of the C1–C4 vertebrae and the superior angle of the scapula.

3. Greater and lesser rhomboid muscles (m. rhomboideus major et minor)

    - The main function is to retract the scapula, but they also participate in lifting it upwards.

Muscles responsible for scapular protraction (moving the shoulder forward)

1. Serratus anterior muscle (m. serratus anterior)

    - The main muscle responsible for protraction of the scapula.
    - It attaches to ribs I–IX and the medial border of the scapula.
    - It allows the shoulder blade to move smoothly along the chest wall and stabilizes it when the arm is raised.

2. Pectoralis minor muscle (m. pectoralis minor)

    - It is responsible for retraction and slight depression of the scapula, but can also assist in protraction, especially when the serratus anterior muscle is weakened.

3. Pectoralis major muscle (m. pectoralis major)

    - It indirectly influences protraction by acting on the humerus, especially during adduction and internal rotation of the arm.

Clinical significance:

Excessive scapular protraction, often caused by weak back muscles, can lead to a rounded back, shoulder pain, and neck pain.

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Weakness of the serratus anterior muscle can cause scapular destabilization and scapular winging.

Muscles responsible for scapular retraction (pulling the shoulders back)

1. Trapezius muscle – middle part (m. trapezius, pars transversa)
    - The main force responsible for scapular retraction.
    - Stabilizes the shoulder blades during movements of the upper limb.
    - Particularly active during exercises such as "face pull" or "reverse fly."
2. Greater and lesser rhomboid muscles (m. rhomboideus major et minor)
    - They pull the shoulder blade towards the spine and slightly upwards.
    - Active, among other things, in posture correction and conscious retraction of the shoulder blades.
3. Latissimus dorsi muscle (m. latissimus dorsi)
    - Although its primary function is to adduct and extend the arm, it can assist in scapular retraction when the limb is stabilized.

Clinical significance of scapular retraction:

Shoulder and arm stabilization

Protection against impingement syndrome

A key element of posture defect therapy, especially in people leading a sedentary lifestyle [1, 2, 27, 28]

Fixed scapular position winging) may lead to adaptive shortening of the pectoralis minor muscle (m. pectoralis minor), which additionally promotes the position of the scapula in protraction , internal rotation and forward tilt [29]. Such an incorrect posture often co-occurs with weakness of the serratus anterior muscle (m. serratus anterior), and its consequence may be disturbed kinematics in the scapulothoracic joint.

Changing the position of the scapula affects not only the local function of the shoulder, but may also affect the entire postural complex – leading to compensatory positioning of the cervical and thoracic spine, a hunched posture in a sitting position, persistent neck pain and excessive activation of the upper part of the trapezius muscle (m. trapezius , pars descendens) [30,31].

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Abnormal scapular orientation alters the biomechanics of the rotator cuff, disrupting the line of pull of its muscles and limiting their ability to control arthrokinematics and dynamic stabilization of the shoulder joint (GH) during abduction [32].

1. The relationship between latissimus dorsi weakness and overactivity of the shoulder abductor muscles is an important clinical aspect, especially in the context of muscle imbalance , compensatory mechanisms, and impaired movement and postural control of the shoulder girdle. The latissimus dorsi muscle performs key functions in extension, adduction, and internal rotation of the arm, and is also involved in scapular depression and stabilization of the glenohumeral joint (GH). It stabilizes the shoulder during complex movements, especially in strength activities such as pull-ups or rowing, supports control of shoulder lowering, and prevents excessive arm elevation.

Latissimus muscle weakness dorsi , a number of functional changes are observed. The lack of support for shoulder adduction and stabilization forces smaller muscles, such as the rotator cuff, to compensate. Furthermore, insufficient scapular depression leads to an elevation position, which in turn promotes increased activation of the shoulder abductor muscles, primarily the upper deltoid and supraspinatus. Impaired scapular and GH joint mechanics can result in compensatory upward and lateral movement (abduction), often with excessive activation of the upper trapezius and trapezius dorsi.

Overactivity of the shoulder abductor muscles in the context of compensation involves the following structures:

Deltoid muscle (middle part) acts as the main abductor, however, it may show excessive activation in the absence of primary stabilization, which leads to its overload and incorrect biomechanics of movement.

Supraspinatus muscle plays a key role in initiating shoulder abduction. Overactivity of this muscle may result from compensating for weakened synergistic muscles, which can lead to overuse and functional impairment.

The upper trapezius muscle is activated secondarily during shoulder elevation, acting as a support rather than a shoulder depression, which may contribute to abnormal scapular dynamics.

In advanced cases, overactivity of these muscles can lead to scapulohumeral rhythm disorders and overload of the shoulder structures , such as subacromial impingement , which increases the risk of pain and injuries in the shoulder joint [33,34].

2. Shoulder dislocations

A shoulder dislocation is an injury in which the head of the humerus slips out of the shoulder socket. This event can lead to changes in shoulder alignment, both temporary and permanent. Joint instability often occurs after a dislocation, which can cause malalignment of the scapula and arm. For example, after an injury, the scapula may shift or rotate, as well as changes in the shoulder angle, which impacts the function and biomechanics of the shoulder girdle. Prolonged or repeated dislocations can lead to

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permanent deformity, weakening of stabilizing structures, and malalignment of the shoulder, which in turn increases the risk of further injury and limits range of motion.

Shoulder dislocations can be divided into several basic types, depending on the direction in which the head of the humerus slips out of the socket. Here are the most common types:

- Anterior shoulder dislocation – the most common type of shoulder dislocation, in which the head of the humerus slips forward, usually as a result of trauma, such as a fall onto an outstretched arm with abduction and external rotation. This dislocation is often associated with damage to the anterior ligaments and structures that stabilize the joint.
- Posterior dislocation – Less commonly, this occurs when the head of the humerus slips backward. It can occur as a result of a severe impact, such as during car accidents or rear-end collisions, or as a result of a convulsion that causes excessive rotation and posterior displacement of the head of the humerus.
- Inferior dislocation (infrasplasia) – a rare condition where the head of the bone slips downwards, usually as a result of a major trauma, e.g. a fall from a height, causing stretching or tearing of the structures below the joint.
- Superior dislocation (supra- and infraglenoid) – less common, when the head of the bone slides upwards or in the supraglenoid direction, often as a result of high-force trauma [35, 54].

3. Functions of the biceps muscle in the shoulder area

The long head acts as an intra-articular dynamic stabilizer , preventing excessive forward and upward translation of the humeral head.

It helps maintain the centering of the humeral head in the socket during arm movements (especially abduction and external rotation).

When the rotator cuff is weakened, the long head of the biceps often takes over the stabilizing role , which can lead to its overload (so-called biceps tendinopathy).

Excessive tension in the biceps (especially the short head) can pull the scapula forward and down , deepening the protracted posture .

Shortening causes the arm to internally rotate and extend forward [36, 37, 38, 39].

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4. The role of the subscapularis muscle in the shoulder complex

As part of the rotator cuff , the subscapularis muscle acts in opposition to the deltoid muscle – it prevents the humeral head from lifting upwards , keeping it centered in the joint socket.

The arm is placed in internal rotation – palms facing backwards.

Increased tension may push the humeral head forward, causing anterior shoulder impingement [40,41].

5. Functions of the long head of the triceps in the context of the shoulder:

The long head, due to its attachment to the scapula, stabilizes the posterior and lower part of the shoulder joint , especially during movements of the upper limb in abduction and external rotation.

Helps limit anterior displacement of the humeral head (along with the subscapularis and glenoid labrum).

Pulls the arm to straighten [42].

6. Teres minor muscle

The teres minor muscle , a component of the rotator cuff, is responsible for external rotation of the shoulder joint and contributes to stabilizing the humeral head relative to the glenoid. Excessive tension or shortening of this muscle can lead to increased pressure of the humeral head against the glenoid, potentially limiting the range of motion in flexion and abduction.

In the postural aspect, symmetrical bilateral tension of the external rotator muscles, including the teres minor, may result in retraction of the shoulder girdle and external rotation of the arms, which is particularly observed in people with the so-called "retracted" shoulder posture.

In athletes who perform repetitive throwing movements, such as throwers, shortening of the teres minor along with the infraspinatus muscle may contribute to the occurrence of posterior-superior subacromial impingement (ISP) . impingement). This leads to compression of the posterior structures of the shoulder joint – especially the supraspinatus tendon and the posterior part of the joint capsule – between the head of the humerus and the posterior edge of the glenoid [43,44].

7. Supraspinatus muscle, as one of the main stabilizers of the humeral head and the initiator of abduction in the shoulder joint, plays a significant role in centering the humeral head relative to the glenoid socket. Excessive tension or increased resting tone can cause the humeral head to be pulled

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upward, resulting in a reduction of the subacromial space . This reduction in space predisposes to the development of subacromial impingement syndrome . impingement syndrome), especially with repetitive movements of abduction and flexion of the upper limb.

From a postural perspective, excessive activity of the supraspinatus muscle often coexists with compensatory tension of the upper trapezius muscle (m. trapezius pars descendens), which can lead to a raised shoulder girdle, increased tension in the neck muscles, and impaired biomechanics of the shoulder complex. [45,46].

8. Infraspinatus muscle

A member of the rotator cuff, plays a key role in external rotation of the shoulder and in stabilizing the humeral head in the glenoid socket. Excessive activity or shortening of this muscle can lead to a compensatory position of the shoulder in a position of slight external rotation, often manifested by a palm-forward resting posture.

Prolonged infraspinatus tension can cause pain in the posterior shoulder, which can be misinterpreted as glenohumeral joint problems. These symptoms are often associated with compression of the posterior structures of the shoulder joint, particularly during abduction and external rotation.

In athletes performing repetitive throwing movements – such as baseball players or javelin throwers – limited internal rotation (IR) combined with tension in the posterior musculoskeletal complex (mainly the infraspinatus and the posterior part of the joint capsule) can lead to the so-called posterior-superior shoulder impingement (IUS) . impingement). The supraspinatus tendon and the posterior-superior capsule become pinched between the head of the humerus and the posterior edge of the glenoid [47, 48].

9. Teres major muscle (m. teres major) is a structure located in the posteromedial part of the shoulder girdle that plays a crucial role in adduction , extension, and internal rotation of the arm at the glenohumeral joint. Due to its attachments and fiber layout, this muscle can contribute to limited external rotation, especially when excessively tight or shortened.

In the context of body posture, increased tension in the teres major muscle can promote shoulder retraction, but with a simultaneous predominance of internal rotation. This pattern can lead to so-called "chest closure"—anterior flexion of the shoulder girdle, limited scapular mobility, and increased pectoral muscle tension.

By influencing the biomechanics of the shoulder joint, a tense teres major muscle can exert an anterior and inferior force on the humeral head, which can result in its translation in these directions. This change in the loading axis can disrupt the stability and proper path of motion in the shoulder joint. Clinically, the shoulder is observed to be internally rotated, adducted, and slightly lowered, which promotes postural rounding of the shoulders and anterior and lateral displacement of the scapula [49, 50].

10. Deltoid muscle (m. deltoideus), as the primary abductor and dynamic stabilizer of the shoulder joint, plays a key role in lifting the upper limb. It consists of three parts: anterior (clavicular), middle

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(shoulder), and posterior (spine), each of which has a distinct effect on the kinematics of the shoulder joint. Under normal conditions, this muscle cooperates with the rotator cuff to center the humeral head relative to the glenoid fossa.

In cases of muscle imbalance , particularly with weakness or delayed activation of the rotator cuff muscles (especially the supraspinatus), increased activity or shortening of the deltoid muscle can lead to upward displacement of the humeral head. This translation reduces the subacromial space . space), which predisposes to the development of subacromial impingement syndrome impingement syndrome) and secondary overload of the rotator cuff tendons.

Posturally, the dominance of the anterior part of the deltoid muscle may result in the head of the humerus being pushed forward, which manifests itself as rounded shoulders and may be associated with compensatory tension of the neck and shoulder girdle muscles – especially the trapezius muscle (pars descendens) and the levator scapulae muscle (m. levator scapulae) [51,52].

11. Coracobrachialis muscle (m. coracobrachialis), which runs from the coracoid process of the scapula to the medial part of the humeral shaft, is responsible for flexion and adduction of the arm at the glenohumeral joint. In the biomechanics of the shoulder girdle, its action can influence the positioning of the glenohumeral joint and the entire scapula, especially in conditions of muscle imbalance.

When the coracobrachialis muscle is shortened or overtightened, there is a tendency for the humeral head to be pulled anteriorly and adducted , resulting in an abnormal posture with rounded shoulders (so-called protraction posture). This pattern can also promote anterior displacement of the scapula and downward rotation, weakening the stabilization of the glenohumeral joint and contributing to overloading of the anterior portion of the joint capsule.

Maintaining such a posture for a long time may negatively affect the length and tension of antagonist muscles (e.g. the infraspinatus and teres minor), which disrupts balanced shoulder kinematics and increases the risk of overload syndromes.

12. Latissimus dorsi muscle

Shoulders rotated inwards, rounded arms, possible displacement of the scapula downwards and forwards [53].

13. Serratus anterior muscle (m. serratus anterior) is responsible for protraction of the scapula, its external rotation and elevation of the lateral angle during lifting of the upper limb. In conditions of functional shortening (e.g., during long-term work at a computer, with rounded shoulders), this muscle may excessively pull the scapula towards the chest, leading to its anterior tilt (anterior tilt) and protraction .

This altered position of the scapula may result in:

- reduction of the subacromial space and predisposition to impingement syndrome ,
- limited range of external rotation and abduction of the shoulder,
- scapulohumeral rhythm disturbance,
- compensatory overload of the neck muscles and upper trapezius.

Additionally, the shortened m. serratus anterior may limit scapular retraction, which exacerbates dysfunctional postural patterns such as the so-called round shoulder posture [55-58].

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