Activity of the long head of the biceps brachii tendon in glenohumeral joint kinematics

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Abstract
The shoulder girdle is a very complex musculoskeletal unit that requires the coordinated activation of muscles extending from the chest to the elbow. The glenohumeral joint has the characteristics of an active joint that does not bear weight, leading to significant bone and muscle changes and frequent tendon overload. Control of glenohumeral stability is achieved by a complex interaction between static and dynamic stabilisers. Tension in the biceps long head tendon has a complex effect on the function of the shoulder joint. It is not sufficient to describe the action of the biceps tendon in its anatomical position alone, because its action is strongly dependent on the position of the glenohumeral joint. The results obtained show the significance of the impact of LHB, but differed in their approach and choice of evidence parameters.

Aktivnost dolge glave biceps brahii pri kinematiki glenohumeralnega sklepa

Povzetek
Ramenski obroč je zelo kompleksna mišično-skeletna enota, ki zahteva usklajeno aktiviranje mišic od prsnega koša do komolca. Glenohumeralni sklep ima značilnosti aktivnega sklepa, ki ne prenaša teže, zaradi česar prihaja do znatnih kostnih in mišičnih sprememb ter pogostih preobremenitev tetiv. Nadzor glenohumeralne stabilnosti se doseže s kompleksno interakcijo med statičnimi in dinamičnimi stabilizatorji. Napetost v tetivi bicepsa z dolgo glavo kompleksno vpliva na delovanje ramenskega sklepa. Opis delovanja tetive bicepsa samo v njenem anatomskem položaju ne zadostuje, saj je njeno delovanje močno odvisno od položaja glenohumeralnega sklepa. Dobljeni rezultati kažejo na pomembnost vpliva LHB, vendar so se razlikovali po pristopu in izbiri dokaznih parametrov.

INTRODUCTION

The biceps brachii is a large, thick muscle on the ventral part of the upper arm. It consists of a short head (caput breve) and a long head (caput longum). The short head originates from the tip of the coracoid process and the long head from the supraglenoid tubercle (tuberculum supraglenoidale). The two heads pass distally and unite to form the muscle belly, then taper over the anterior part of the elbow and attach via the bicipital aponeurosis to the radial tuberosity and fascia of the forearm (Eames et al, The tendon is approximately 5 to 6 mm in diameter and approximately 9 cm in length. The size of the tendon varies, the intra-articular part is usually wide and straight, while the extra-articular part is rounder and smaller (Elser et al., 2011). The antagonist of the biceps muscle is the triceps brachii muscle (Créteur et al., 2019). The long head of the biceps (LHB) and the glenoid labrum act as a functional unit, the biceps labrum complex (BLC). The biceps labrum complex is divided into three distinct anatomical regions: the interior, the junction and the bicipital tunnel (Taylor et al., 2019). The stabilising mechanisms of the shoulder joint are broadly divided into static and dynamic. The bony anatomy, negative intra-articular pressure (NIAP), labrum, capsule and glenohumeral ligaments represent static stabilisers. The rotator cuff (RC) muscles are considered to be the main dynamic contributors to shoulder stability. The capsule, glenohumeral ligaments, glenoid labrum, RM muscles, of which the LHB is a component, and the glenohumeral obliques are part of a complex system that controls the movement of the humeral head within the glenoid fossa (Pagnani et al., 1996). The anatomy of the RC is ideal for providing compression loading throughout the full range of motion of the glenohumeral joint. The potential effectiveness of the concavity compression mechanism is limited by the strength of the RC and other compression muscles and by the relatively small size of the glenoid, which is only one quarter the size of the articular surface of the humeral head (Lippitt et al., 1993). RC contraction compresses the humeral head into the glenoid fossa, so a greater force is required to translate the humeral head. In addition, some authors have suggested that selective contraction of the RC muscles may allow adaptations in response to changes in capsulo ligamentous tension. If the RC is injured or inactive during a particular activity, or if the capsular ligaments are damaged, biceps activity may be increased. However, loss of biceps function can result in increased glenohumeral translation, which worsens clinical symptoms (Pagnani et al., 1996). The biceps brachii muscle is primarily a strong supinator of the forearm but a weak flexor of the elbow (Busconi et al., 2008). Research authors also attribute a number of roles to the tendon of the long head of the biceps (TLHB). Most biomechanical studies that have investigated the role of the TLHB have focused on its contribution to glenohumeral stability, which inhibits abnormal translations. With few exceptions, these studies have been carried out in cadaveric models. Biomechanical studies in cadaveric models cannot reproduce the many factors that work in synergy to ensure glenohumeral stability in vivo. A limitation of biomechanical studies on cadavers is that they do not apply physiological stresses on the LHB (Elser et al., 2011). Some researchers believe that its only function is to attach the LHB to the glenoid. Biomechanically, the TLHB has a controversial role in the dynamic stability of the shoulder joint. It has been shown, mainly in biomechanical studies on cadavers and animal models, that the tendon plays at least a passive stabilising role in the shoulder. Charles S. Neer (1972) proposed in the 1970s that the stabilising role of the LHB varies according to the position of the elbow. Several subsequent studies have refuted the theory that the TLHB has an active stabilising role in the shoulder (Charalambous & Eastwood, 2013). Jobe et al. (1984) assessed biceps activation during the throwing motion in athletes. The authors reported that maximal muscle stimulation occurred in association with elbow flexion and forearm deceleration, with very little proximal biceps activity during the earlier phases of the throwing motion (Jobe et al., 1984). The role of the LHB is unclear due to anatomical variations and conflicting findings.

METHODS

In this thesis, we used a descriptive method, examining the literature in English and Slovenian published between 2000 and 2023. The literature review included the identification of inclusion and exclusion criteria for the selection of the literature, an assessment of the quality of the included literature, and an analysis of the results. The literature search strategy, selection, quality assessment and data extraction were based on a review of titles to assess the relevance of the articles and to exclude those that were not included. Abstracts and studies were assessed on the basis of the inclusion and exclusion criteria already established.

The literature search was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2010). The literature search was performed using the following databases, PubMed, MEDLINE, Physiotherapy Evidence Database (PEDro), Elsevier, ScienceDirect, and the Slovenian reciprocal bibliographic system COBISS April 2023, with Google Scholar as an add-on. The literature search was performed using the following keywords: anatomy, biceps brachii, long head of biceps, tendon, shoulder, glenohumeral stability, function, palpation, assessment.

In line with the PICO strategy, population, intervention, comparison, observed outcome (Liberati et al., 2009), we selected inclusion criteria as follows. (1) Population: studies that included adults of both sexes, with or without injury and surgical treatment, and biomechanical studies in cadavers. (2) Intervention: different measurement techniques and activities to demonstrate the role of the LHB. (3) Comparison: comparison of shoulder joint arthrokinematics under LHB loading, EMG LHB activity, comparison of shoulder joint translation and rotation under LHB activity. (4) Observed outcome: LHB activity.

Randomised controlled trials, controlled studies, experimental studies, review articles and pilot studies were included. We excluded studies in other languages, studies that contained only an abstract, studies that examined biceps brachii muscle activity only at the elbow joint, and semi-scientific studies.

RESULTS

Based on the selected keywords, 750 studies were retrieved from the databases, of which 58 were eligible for full-text review. After screening, 48 articles were excluded as the studies did not fit the PICO strategy. In the end, 15 studies met the inclusion and exclusion criteria. The systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2010).

The sample of 15 studies included 186 subjects. The mean age in the 11 studies was 48.6 years (Alexander et al., 2013; Chalmers et al., 2014; Eshuis & De Gast, 2012; Giphart et al., 2012; Kim et al., 2014; Landin et al., 2017; Levy iet al., 2001; McGarry et al., 2016; Su et al., 2010; Swaringen et al., 2006; Youm et al., 2009). Seven studies have been conducted on cadaveric shoulder joints (Alexander et al., 2013; Eshuis & De Gast, 2012; Halder et al., 2000; Hanypsiak et al., 2012; McGarry et al., 2016; Su et al., 2010; Youm et al., 2009). Five studies on cadavers reported a mean age of 71.1 years (J. G. Alexander et al., 2021; Eshuis & De Gast, 2012; McGarry et al., 2016; Su et al., 2010; Youm et al., 2009). However, two studies on cadaveric shoulders did not report this information (Halder et al., 2001; Hanypsiak et al., 2012). Similarly, the mean age was not reported by two in vivo studies (David et al., 2000; Levy et al., 2001), eleven studies included 154 subjects and reported the sex of the subjects (S. Alexander et al., 2013; Chalmers et al., 2014; David et al., 2000; Giphart et al., 2012; Kim et al., 2014; Landin et al., 2017; Levy et al., 2001; McGarry et al., 2016; Nejat et al., 2012; Su et al., 2010; Swaringen et al., 2006). The sample size of these individual studies ranged from 4 to 38 subjects, with an average of 33.8 subjects. Men dominated the studies, at 9.3%, while women were represented at

4.8%. Two studies included only men (David et al., 2000; Levy et al., 2001), and nine studies included both men and women, with the balance skewed in favour of the male population. Four studies did not provide data on gender representation (Eshuis & De Gast, 2012; Halder et al., 2001; Hanypsiak et al., 2012; Youm et al., 2009). Six in vitro cadaveric studies investigated the role of LHB in shoulder stability (S. Alexander et al, 2013; Giphart et al., 2012; Halder et al., 2001; McGarry et al., 2016; Su et al., 2010; Youm et al., 2009). Three studies investigated the role of LHB as a depressor of the humeral head (S. Alexander et al., 2013; Halder et al., 2001; McGarry et al, One study investigated the role of the LHB as a compressor of the glenohumeral joint (Hanypsiak et al., 2012). Two studies investigated the effect of the LHB on rotations (Eshuis & De Gast, 2012; Hanypsiak et al., 2012). Two studies investigated the effect of the LHB on translation (Su et al, Electromyographic activity of LHB has been studied in seven studies (Chalmers et al., 2014; David et al., 2000; Giphart et al., 2012; S.-H. Kim et al., 2001; Levy et al., 2001; Nejat et al., 2012; Swaringen et al., 2006).

DISCUSSION

Although much is known about the anatomy of the long head of the biceps (LHB), the function of this structure remains unclear. This is also contributed to by the theory that most LHB symptoms occur secondary to other pathology in the shoulder joint. Conditions such as bursitis, impingement, instability and damaged labrum often involve palpatory tenderness of the LHB. The opinions of researchers vary widely, from that it has no function in the shoulder to that it provides glenohumeral stability in all directions.

Numerous studies have attempted to establish the role of the LHB tendon in the glenohumeral joint (Andrews et al., 1985; Halder et al., 2001; Itoi et al., 1996; Kido et al., 2000; Kumar et al., 1989; Landin et al., 2017; Levy et al., 2001; Neer 2nd, 2005; Rodosky et al., 1994; Sakurai et al., 1998; Yamaguchi et al., 1997), which can be broadly classified into one of three categories: (1) studies showing that the LHB tendon plays a role in stabilizing the glenohumeral joint, particularly in stabilizing the humeral head (Itoi et al, 1993; Kumar et al., 1989; Rodosky et al., 1994; Warner et al., 1998); (2) research showing that the LHB plays an active role in the glenohumeral joint (Chalmers et al., 2014; S.-H. Kim et al, 2001; Sakurai et al., 1998; Swaringen et al., 2006); and (3) research showing that the LHB does not play a significant role in the glenohumeral joint (Landin et al., 2017; Levy et al., 2001; Yamaguchi et al., 1997).

Therefore, the hypothesis that "there is reliable evidence that a long head of biceps has a significant effect on both the kinematics and stability of the glenohumeral joint" cannot be fully supported, as the research has not come to clear, uniform conclusions. All 15 studies mostly reported the significance of the effect of LHB, but they differed in their approach and choice of evidence parameters.

The stabilising role of the LHB tendon in the glenohumeral joint is one of the most studied areas (Itoi et al., 1993; Kido et al., 2000; Kumar et al., 1989; Rodosky et al., 1994). All these studies have shown that the LHB tendon plays an important role in the stabilisation of the glenohumeral joint in two different positions. The LHB tendon has been shown to contribute to limiting anterior translation of the humeral head when the glenohumeral joint is in a position of abduction and external rotation (Eshuis & De Gast, 2012; Itoi et al., 1993; McGarry et al., 2016; Rodosky et al., 1994). The abduction and external rotation position is a position often seen in over-the-horizon movements and is reached during the late cocking phase of the throw (Andrews et al., 1985). Researchers have suggested that in this position the LHB tendon helps to prevent anterior translation by developing torsional stiffness (Rodosky et al., 1994). When the arm is in abduction and external rotation, tension in the biceps tendon increases, resulting in increased torsional stiffness of the shoulder. Similar results were also obtained in a study conducted by David et al. (2000), who demonstrated that prior to the initiation of the rotation movement, there is an increase in the activity of the rotator cuff (RM) and LHB muscles, which is mainly directed towards increasing the stiffness of the shoulder joint and thus its stability.

By increasing the tension of the tendon of the long head of the biceps (LHBT), the force required for external rotation of the shoulder increases by 32% (David et al., 2000; Rodosky et al., 1994). Contrary findings were reached by Giphart et al. (2012), who in one study used fluoroscopy to determine glenohumeral translation during dynamic movement in patients undergoing subpectoral tenodesis of the LHBT, the fixation of the LHBT to the humerus. They found that glenohumeral kinematics did not change, less than 1 mm, in the tenodesis patients, the humeral head was centred slightly anteriorly during abduction and the simulated eccentric phase of late flattening. However, due to the small sample size, no statistical analysis was performed. One of the limitations often reported in cadaveric studies was the determination of appropriate biceps forces in vitro that would accurately reflect the normal physiological loading of the LHB in vivo. Interpretation of cadaveric studies is difficult due to the inability to reproduce the dynamic interaction of the surrounding musculature.

In the study by Su et al. (2010), a biceps force of 55 N was applied and calculated from the physiological cross-sectional area of the biceps brachii. They found that loading the LHB led to a significant reduction in anterior and superior glenohumeral translation in all RC tear sizes, with a greater reduction in the percentage of glenohumeral translation in larger tears. The function of the LHB as a depressor of the humeral head has been demonstrated in the injured RC by Kido et al., (2000). They found that the LHB compresses the humeral head into the glenoid during active contraction at 0°, 45° and 90°, confirming the study by Warner & McMahon, (1995) that a ruptured LHBT causes the humeral head to move superiorly. It should be noted that Kido et al. (2000) studied the influence of the entire biceps brachii muscle, while Su et al. (2010) separated the influence of the long and short head (LH). They found that the LH has a greater influence on depression than the short head, suggesting a greater role of the LHB. Similar conclusions were reached in four in vitro studies by J.G. Alexander et al, (2021), Halder et al, (2001), McGarry et al, (2016) and Youm et al, (2009), where they investigated the translation of the humeral head during and after loading of the LHB and found that the LHB reduces translations in all directions when loaded; anterior, posterior, inferior and superior. Based on the results of the studies, it can be concluded that strengthening of the LHB has a beneficial effect on humeral head stabilisation in unstable shoulder joint and shoulder impingement. Unlike other studies, Alexander et al. (2013) perforated the intact joint capsule to artificially induce instability of the GH joint. A drawback of this study is that the RC muscles were not involved. In vivo, the resting tone of these muscles could compensate for translational changes. The relative activity of the different muscles may vary according to the position of the joints, but this complex relationship is not known in vitro. In addition, no pressure was applied to the articular surface that could contribute to the centring and stabilisation of the humeral head. In vitro studies have a number of limitations, including inferior tissue stretch, absence of dynamic muscle forces, joint proprioception and coordination. The high age of cadaveric specimens may be a confounding variable when relating results to those of younger cadaveric specimens. However, research has shown that the biomechanical properties of the soft tissues in the glenohumeral joint can be similar between young and old cadaveric samples within functional ranges of motion (Youm et al., 2009). Two studies used progressive biceps loads of 10, 20 and 40 N based on previously calculated biceps brachii cross-sectional values (Hanypsiak et al., 2012; McGarry et al., 2016). Both studies demonstrated a significant effect of LHB on humeral head depression and GH joint stabilisation. Hanypsiak et al. (2012) concluded that LHB unloading displaces the humeral head posteriorly during the late tension phase, leading to RC compaction and tears. In athletes with tenodesis performed who engage in the over-the-horizon throwing technique, this would present negative consequences.

The long head of the biceps can be an important secondary stabiliser of the glenohumeral joint. Kim et al (2001) performed an EMG study to monitor elbow and forearm movement. The tension of the biceps brachii muscle was significantly greater in the unstable shoulder than in the opposite, stable shoulder in all arm positions. The muscle tension in the unstable shoulder was greatest at 90° and

120° of external rotation. The results suggest that the LHB plays an active compensatory role in the unstable shoulder in abduction and external rotation. Similar results were reached by Chalmers et al. (2014), who demonstrated that with immobilization of the forearm and elbow and loading of the distal part of the humerus, the EMG activity of the LHB increases in both anteflexion and abduction, suggesting that this muscle plays a dynamic role in complex glenohumeral movement.
However, it is important to bear in mind that in everyday life, shoulder joint activity also involves movement at the elbow and forearm, including synergistic contraction of the associated muscles.

CONCLUSIONS

The long head of the biceps is still a poorly understood structure from a functional point of view, in contrast to its anatomy, where a large number of intra-articular variations are known. In the past, the LHBT was considered to be an active depressor and static stabiliser of the glenohumeral joint. It acts as an effective depressor of the humeral head and maintains adequate tension in some glenohumeral ligaments, as predicted by the concept of complementary stability of the shoulder. Loss of DGB function results in an increase of forces in the glenohumeral ligaments and is associated with superior displacement of the articular surface of the glenohumeral joint. In patients with DGB rupture, the humeral head is displaced superiorly during abduction (Abboud & Soslowsky, 2002; Halder et al., 2001). Although the biceps is thought to be a depressor of the humeral head, the increased EMG activity of the biceps in anteriorly unstable shoulders during throwing suggests that the biceps may also compensate for glenohumeral joint instability. LHBT tension has a complex influence on shoulder function. When the biceps is loaded, anterior-posterior translation is markedly reduced, especially during external rotation. In artificial Bankart injuries, the DGB is more important than any other RM muscle for stabilising the glenohumeral joint. Instability of the LHBT and its connection to the superior part of the labrum, the SLAP lesion, may result in loss of effective depressor function of the tendon. Pagnani et al. (1996) found that application of force to the LHBT reduced anterior-posterior and superior-inferior translation, but also found that the tendon normally stabilises the joint anteriorly when the arm is in internal rotation and serves as a posterior stabiliser when the humerus is in external rotation.
The inconsistency in research suggests that there is not yet a definitive understanding of the role of the DGB in the glenohumeral joint. It is important to understand the precise function of the LHB as it affects rehabilitation and surgical treatment options for individuals with proximal LHBT pain or labrum pathology.
The authors found that the role of LHB is altered in the failure. In the case of RC ligament injury, it contributes more to shoulder depression, and its electromyographic activity increases. It is likely that the LHB contributes similarly to anterior stability in anteriorly unstable shoulders, as its activity increases then, but further research would be needed to confirm this. The results of the studies show that the sensorimotor system of the shoulder joint is well adapted and therefore the LHB is also well adapted. The activity of the LHB may increase or decrease with a given impairment. Its role in the kinematics of the GH joint is therefore not unique and may vary from person to person.

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